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Featured Article

Video Analysis of Newborn Resuscitations After Simulation-Based Helping Babies Breathe Training

Ingunn Anda Haug, MSc[a,*], Kari Holte, MD[b], Catherine L. Chang, MD[c], Carolyn Purington, MPH[d,e], Joar Eilevstjønn, PhD[a], Anita Yeconia, NO[f], Hussein Kidanto, MD, MMED, PhD[g], Hege L. Ersdal, MD, PhD[h,i]

[a]*Laerdal Medical, Stavanger, Norway*
[b]*Østfold Hospital Kalnes, Grålum, Norway*
[c]*Weill Cornell Medicine, Weill Cornell Medicine, New York, NY 10021, USA*
[d]*Laerdal Global Health, Stavanger, Norway*
[e]*Center for Healthcare Organization & Implementation Research (CHOIR), Edith Nourse Rogers Memorial Veterans Hospital, Bedford, MA, USA*
[f]*Haydom Lutheran Hospital, Mbulu, Manyara, Tanzania*
[g]*School of Medicine, Aga Khan University, Dar es Salaam, Tanzania*
[h]*Stavanger University Hospital, Stavanger, Norway*
[i]*University of Stavanger, Stavanger, Norway*

KEYWORDS
newborn resuscitation;
simulation-based training;
helping babies breathe;
video analysis;
low-resource setting

Abstract

Background: Simulation-based Helping Babies Breathe (HBB) training is currently rolled-out in around 80 low-income countries with various results.

Method: Workflow was analyzed in 76 video-recorded newborn resuscitations performed by regularly HBB-trained nurse-midwives over 3 years in rural Tanzania.

Results: Actual newborn resuscitation practice deviated from HBB intention/guideline: most newborns underwent prolonged suction and stimulation before ventilation; ventilation was delayed and frequently interrupted. Nurse-midwives often worked together.

Conclusions: There is a gap between training intention and clinical practice. HBB trainings should focus more on urgency, ventilation skills, and team training. Combining clinical debriefing with HBB simulations could facilitate continuous learning and application.

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* Corresponding author: Ingunn.haug@laerdal.com (I. A. Haug).

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Globally, almost four million newborns die each year. Many of these deaths occur secondary to intrapartum-related events, often called birth asphyxia, defined as failure to initiate or sustain spontaneous breathing at birth (Lee et al., 2013; Msemo et al., 2013). Estimates suggest that 10% of all newborns, that is, 13.5 million babies per year, have problems breathing at birth, and birth asphyxia is estimated to account for about 717,000 deaths annually (Save The Children, 2014). In addition, one million of the surviving newborns develop neurocognitive problems (Lee et al., 2013).

Key Points

- Newborn resuscitation practice deviated from Helping Babies Breathe simulation training intention, with delayed and interrupted ventilations, and more stimulation and suctioning than recommended.
- Several nurse-midwives were working together in most of the newborn resuscitations.
- Combining Helping Babies Breathing simulation training with clinical debriefings may facilitate continuous learning and application of skills/competence in clinical practice.

Approximately 98% of all newborn deaths happen in low-income countries (Save The Children, 2014). "Helping Babies Breathe" (HBB) is a simulation-based education program developed by the American Academy of Pediatrics with partners, aiming to reduce newborn mortality in resource-limited settings by training providers in basic newborn care and resuscitation. Focus is to start ventilation within the first minute after birth for nonbreathing newborns. (www.helpingbabiesbreathe.org). HBB is under implementation in approximately 80 countries and has the potential to improve patient safety for newborns. However, several reports show diverging results related to outcome (Ersdal et al., 2017).

Haydom Lutheran Hospital (HLH) is a referral hospital in rural northern Tanzania. A one-day HBB simulation-based training was conducted at HLH in April 2010. This improved resuscitation performance in simulations but was initially insufficient to transfer knowledge, skills, and competency into clinical practice (Ersdal et al., 2013). The reduction in perinatal mortality came after implementation of systematic low-dose high-frequency simulation training (Mduma et al., 2015). Continuous focus on frequent HBB simulation training in combination with various quality improvement efforts is reported to save an estimated 250 extra lives over a six-year period, from 2010 to 2017, at HLH (Mduma et al., 2019).

A systematic literature review of newborn resuscitation training concludes that knowledge and skills falloff are barriers for success and that structured retraining may improve retention of knowledge and skills (Reisman et al., 2016). The review also reports that bag-mask ventilation is more difficult to learn than other aspects of newborn resuscitation. According to HBB, ventilation should start within one minute after birth and continue until the baby is breathing well. A previous study from HLH describes delayed startup of ventilation and frequent interruptions (Linde et al., 2017). In addition, in-depth interviews of nurse-midwives revealed that they often feel anxious during newborn resuscitation, fearing that this stress leads to substandard ventilation (Moshiro, Ersdal, Mdoe, Kidanto, & Mbekenga, 2018a). Despite a steady improvement in perinatal outcomes over several years with regular HBB simulation training, further efforts seem warranted to identify possible strategies to enhance learning and translation to clinical situations. To ensure optimal care and further improve patient safety for nonbreathing newborns, there is a need to better understand deviations between recommendations and clinical practice.

The overall aim of this study was to describe workflow during actual newborn resuscitations in a low-resource setting with regular HBB simulation trainings over several years. We wanted to (a) identify gaps between observed clinical practice and HBB intention, (b) describe areas where there is a need for improved focus in the training program, and (c) describe potential differences in resuscitation practice among newborns who survived versus those who died.

Theoretical Framework

Kolb's experimental learning theory is often used as a conceptual framework for simulation-based training programs (Stocker, Burmester, & Allen, 2014). Kolb claims that "Learning is the process whereby knowledge is created through the transformation of experience" and describes the learning process as a circle with four phases: experience, reflection, conceptualization, and experimentation (Figure 1). In the context of this study, the experience derives from the HBB simulation training. The reflection and conceptualization of new knowledge happens during debriefing and discussion. The experimentation, where the

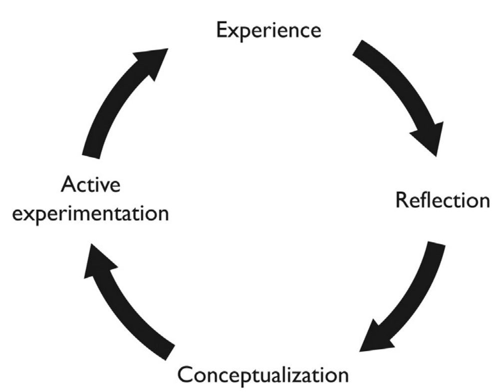

Figure 1 Kolb's learning cycle. Describing learning as transformation of experience through four phases.

new knowledge is applied, can take place in further simulation training or in actual resuscitations.

Material and Methods

Setting

This was an observational video study on workflow during real newborn resuscitations at HLH, a hospital with 400 beds and around 4,000 deliveries annually. The hospital provides comprehensive emergency obstetric care and basic emergency newborn care to a population of approximately 500,000 people and has a referral area of approximately two million people. HLH has six delivery rooms and one operating theatre for caesarian sections. Deliveries and newborn resuscitations are mainly conducted by 15 to 20 nurse-midwives.

Helping Babies Breathe Training

HBB teaches providers how to care for breathing newborns and how to assist newborns not breathing on their own after birth. By one minute after birth, the newborn should be either breathing well, or ventilations should be provided. Decision and action points for crying and noncrying babies

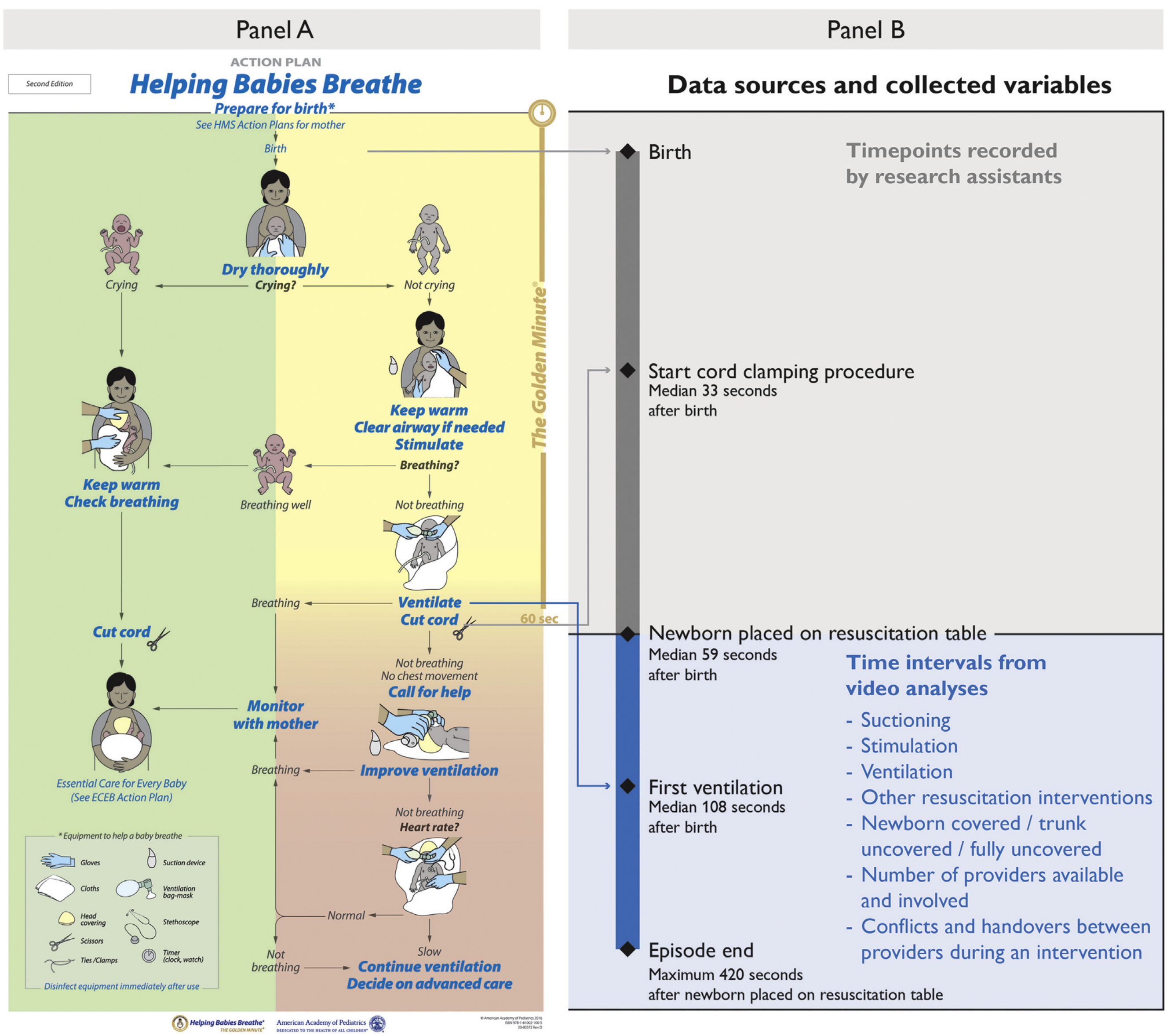

Figure 2 Helping Babies Breathe guideline and illustration of analyzed resuscitation interventions. Panel A: Helping Babies Breathe guideline, describing the decision points and corresponding action points for crying and not crying newborns. Panel B: Overview of analyzed resuscitation interventions and how they deviate from the guideline.

are described in the HBB guideline (Figure 2, panel A). For a noncrying newborn, HBB teaches to keep the newborn warm, suction if needed, and stimulate briefly before moving on to ventilation.

As part of the HBB training, the learners practice newborn resuscitation skills in pairs; one performing the resuscitation while the other operates the NeoNatalie Newborn Simulator (Laerdal Global Health, Stavanger, Norway). Because the HBB curriculum was developed for resource-limited environments, the focus is more on preparing the single provider to help a baby breathe than how to work together as a team.

HBB was introduced to all nurse-midwives at HLH through a one-day training in 2010. Since then, there has been three one-day HBB-trainings, one in 2011 and two in 2015. Five local nurse-midwives were trained as HBB-trainers, with the responsibility to facilitate weekly 5 to 10 minutes simulation trainings in the labor ward. Since 2011, these low-dose high-frequency trainings, focusing on ventilation skills and the HBB guideline, have been mandatory for all nurse-midwives, but also optional for operating nurses, anesthetic nurses, and doctors. Over time, most providers involved in newborn resuscitations have attended these short simulation trainings at least monthly.

Data Collection

This is a substudy of the Safer Births research and innovation project (www.saferbirths.com), aiming to improve perinatal survival worldwide. Since July 2013, newborn resuscitations at HLH have been video recorded. Heart rate and ventilation signal data were recorded by Newborn Resuscitation Monitors (Laerdal Global Health, Stavanger, Norway; Figure 3) mounted over the resuscitation table in each of the delivery rooms and in the operating theatre. The monitor included a self-inflating neonatal resuscitator (bag-mask), sensors between the mask and bag for capturing ventilation flow, pressure, and expired CO_2, a dry-electrode electrocardiogram sensor for heart rate detection, and a display showing the heart rate. Video cameras were installed above the resuscitation tables, capturing the newborns and the hands of the provider(s) during resuscitations.

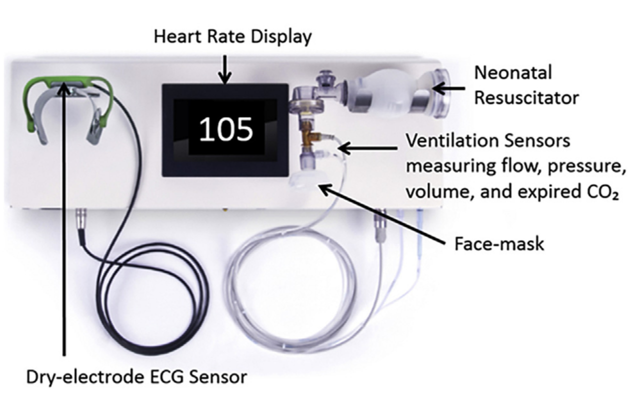

Figure 3 Newborn Resuscitation Monitor and its components used for data collection.

In addition, all deliveries were observed and documented by trained and supervised, nonmedical research assistants (n = 16) who were continuously present in the labor ward, working in three shifts over 24 hours. Three research assistants worked per shift covering the labor ward, operating theatre, and the adjacent neonatal area. Every delivery and newborn were observed, and intervals from birth to different events were timed using stop watches. Newborn characteristics, fetal heart rate, amniotic fluid, labor complications and management, newborn resuscitation, postnatal management, and outcomes were recorded on data collection forms.

Videos and monitor data were downloaded on a weekly basis. Two quality controllers checked that monitor data matched the observational data for each patient. After uploading to the server, data were further reviewed for accuracy and quality.

Included Patients

All live newborns with complete data set, $\geq$34 weeks gestational age who received ventilation between July 2013 and July 2016, were considered for inclusion. Fresh stillbirths (i.e., Apgar score zero at one and five minutes, intact skin, and suspected death during labor/delivery) were excluded.

All eligible newborns who died within three days of birth (n = 30) were included. These were matched (i.e., stratified on initial heart rate) with 46 survivors (newborns with normal outcome), randomly selected as controls, resulting in 76 included patients.

Video Analysis

Video recordings of all selected resuscitations were reviewed by four independent annotators, two physicians (K.H. and C.C.), one product development engineer (C.P.), and one human-factors engineer (I.H.).

The annotators developed an annotation protocol using ELAN (The Language Archive, Nijmegen, Netherlands) to describe the following interventions/variables: stimulation, suctioning, covering of the baby, and description of other resuscitation measures (i.e., chest compressions, intravenous injections, endotracheal intubation, wipe inside mouth, umbilical cord care, and newborn held upside down), based on the visual information on the video recordings. One ‘‘event’’ was defined as any continuous intervention with less than 5-second pause. One ‘‘episode’’ was defined as the whole video annotation, from the baby placed on the resuscitation table until the end of the resuscitation or at maximum 420 seconds after start (Figure 2B).

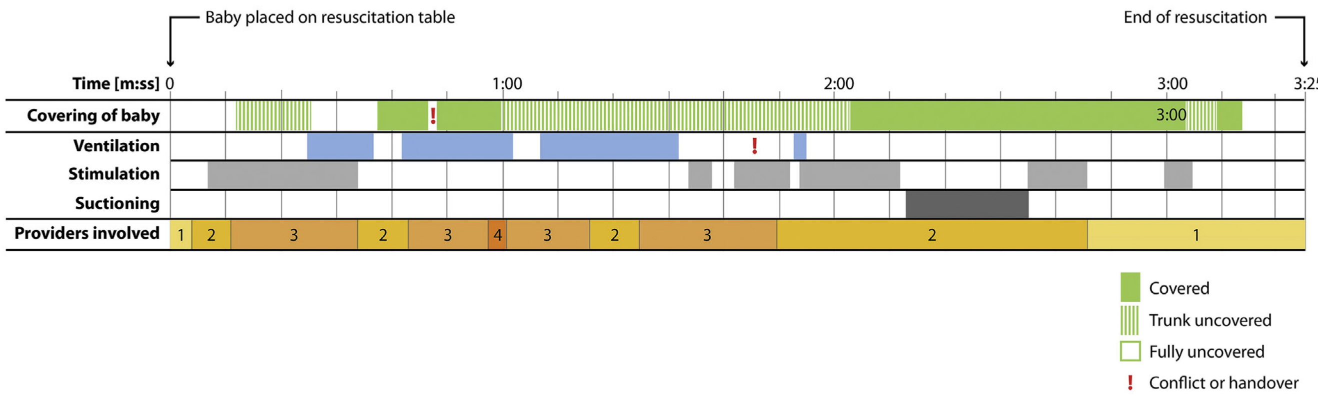

Figure 4 Example of a newborn resuscitation timeline. Illustration of resuscitation interventions and provider involvement during a resuscitation.

First, three annotators independently annotated 10 test videos, not part of the data set, in separate ELAN files, to reach consensus on definition of parameters. Then the protocol was revised, and annotation of study videos commenced. Each study video was reviewed and annotated by two independent reviewers; the 76 videos were randomly assigned to one physician and one engineer. Reviewers were blinded to heart rate, ventilation signal data, newborn outcome, and observational data (obstetric history, perinatal course and outcomes, as well as identities and experience/training of the providers) at the time of annotations.

Following annotation of all 76 videos, annotation files were processed for agreement using Matlab (The Mathworks Inc., Natick, MA). Agreement was considered sufficient if annotations matched ≥80% of the time. If agreement was achieved, either annotation file could be used for analysis. Agreement ≥80% in all parameters was

Table 1 Labor Characteristics and Newborns' Condition at Birth

	All Newborns N = 76	Survivors N = 46	Deaths Within 3 Days N = 30	*p*-Value
Gestational age*, weeks	38 [37, 39]	38 [37, 40]	38 [37, 39]	0.44‡
Birth weight, grams	3,100 [2,690, 3,390]	3,200 [2,800, 3,500]	2,780 [2,530, 3,168]	<0.01‡
Labor complications, n (%)				
No	64 (84)	39 (85)	25 (83)	1.00‖
Yes	12 (16)	7 (15)	5 (17)	
Fetal heart rate during labor, n (%)				
Normal	53 (70)	37 (80)	16 (53)	0.018§
Abnormal	9 (12)	2 (4)	7 (23)	
Not measured	14 (18)	7 (15)	7 (23)	
Amniotic fluid†, n (%)				
Clear	39 (52)	27 (60)	12 (40)	0.22‖
Slight meconium	11 (15)	5 (11)	6 (20)	
Thick meconium	24 (32)	12 (27)	12 (40)	
Blood stained	1 (1)	1 (2)	0 (0)	
Mode of delivery, n (%)				
Vaginal delivery	41/76 (54)	27 (59)	14 (47)	0.58‖
Cesarean section	32/76 (42)	17 (37)	15 (50)	
Breech	3/76 (4)	2 (4)	1 (3)	
Apgar 1	7 [5, 7]	7 [7, 8]	4 [3, 5]	<0.01‡
Apgar 5	10 [8, 10]	10 [10, 10]	9 [6, 10]	<0.01‡

Note. n = number.
* Data missing for four newborns (1 survivor, 3 deaths).
† Data missing for one newborn (1 survivor).
‡ Mann—Whitney *U* test.
§ Pearson chi-square test.
‖ Fisher's exact test.

Table 2 Resuscitation Characteristics and Interventions

	All Newborns N = 76	Survivors N = 46	Deaths Within 3 Days N = 30	*p*-Value
Resuscitation characteristics				
Time from birth to newborn placed on resuscitation table*, s	59 [35, 93]	63 [37, 107]	49 [28, 90]	0.091§
Duration of episode, s	344 [237, 420]	290 [173, 393]	420 [337, 420]	<0.01§
Cut cord HBB intention: Follow your facility's routine for when to clamp or tie and cut the cord. Cutting the cord should not delay the start of ventilation.				
Time from birth to clamp cord†, s	33 [15, 57]	35 [15, 58]	19 [14, 50]	0.16§
Keep warm HBB intention: Keep the baby skin-to-skin on the mother's chest/abdomen. If that is not possible, place the baby on a warm, dry blanket beside the mother. Ask your helper to cover the head				
Fraction of episode time newborn covered, %	35 [15, 63]	40 [25, 67]	26 [12, 55]	0.13§
Fraction of episode time newborn's trunk uncovered, %	16 [6, 39]	12 [2, 31]	24 [14, 58]	<0.01§
Fraction of episode time newborn fully uncovered, %	27 [15, 58]	35 [19, 59]	26 [14, 39]	0.17§
Clear airway if needed HBB intention: Remove secretions from the airway if they are blocking the mouth or nose or if there is meconium in the amniotic fluid. Stop suctioning when secretions are cleared, even if the baby does not breathe. Suctioning too long, too vigorously, too deeply, or too often can cause injury, slow heart rate, and prevent breathing				
Number of newborns suctioned during episode, n (%)	68/76 (89)	42/46 (91)	26/30 (87)	0.71¶
Total fraction of episode time with suctioning, %	13 [7, 21]	14 [7, 21]	11 [5, 21]	0.31§
Number of newborns suctioned before first ventilation, n (%)	46/76 (61)	28/46 (61)	18/30 (60)	0.94‖
Number of newborns suctioned before first ventilation who had meconium/blood stained amniotic fluid, n (%)	26/46 (57)	12/28 (43)	14/18 (78)	0.02‖
Total duration of suctioning before first ventilation, s	22 [13, 44]	23 [14, 50]	22 [10, 34]	0.77§
Number of suctioning events before first ventilation, n	2 [1, 3]	2 [1, 3]	2 [1, 2]	0.26§
Stimulate breathing HBB intention: Rub the back 2 or 3 times gently but firmly. Do not delay or stimulate longer				
Number of newborns stimulated during episode, n (%)	75/76 (99)	46/46 (100)	29/30 (97)	0.40¶
Total fraction of episode time with stimulation, %	28 [15, 37]	32 [24, 37]	19 [11, 27]	<0.01§
Number of newborns stimulated before first ventilation, n (%)	66/76 (87)	40/46 (87)	26/30 (87)	1.00¶
Total duration of stimulation before first ventilation, s	23 [8, 38]	22 [9, 38]	24 [6, 33]	0.65§
Number of stimulation events before first ventilation, n	2 [1, 3]	2 [1, 3]	2 [1, 3]	0.97§
Ventilate HBB intention: Begin ventilation by 1 minute. Continue ventilation for 1 minute before stopping to check the heart rate. Minimize the time without ventilation. Stop ventilation when the baby is breathing and the heart rate stays normal				
Number of newborns ventilated within 60 seconds†, n (%)	11/74 (15)	6/45 (13)	5/29 (17)	0.74¶
Time from birth to first ventilation†, s	108 [76, 158]	104 [73, 176]	125 [81, 146]	0.86§
Time from newborn placed on resuscitation table to first ventilation*, s	57 [27, 76]	48 [27, 76]	60 [30, 74]	0.51§
Duration of first ventilation event, s	9 [6, 17]	9 [7, 16]	10 [5, 24]	0.80§
Number of episodes with first ventilation event at least 60-second duration‡, n (%)	4/74 (5)	1/45 (2)	3/29 (10)	0.29¶
Total fraction of episode time with ventilation, %	11 [22, 45]	15 [9, 24]	46 [23, 66]	<0.01§
Number of episodes with more than one ventilation event, n (%)	67/76 (88)	39/46 (85)	28/30 (93)	0.47¶
Duration of pause between the two first ventilation events, s	8 [5, 24]	8 [5, 29]	8 [5, 20]	0.51§
First intervention within 5 seconds after stop of first ventilation event, n (%)				
No intervention	18/67 (27)	9/39 (23)	9/28 (32)	0.50¶
Suction	4/67 (6)	1/39 (3)	3/28 (11)	
Stimulation	21/67 (31)	13/39 (33)	8/28 (29)	
Shift ventilation	7/67 (10)	4/39 (10)	3/28 (11)	
Improve ventilation	17/67 (25)	12/39 (31)	5/28 (18)	

(*continued on next page*)

Table 2 *(continued)*

	All Newborns N = 76	Survivors N = 46	Deaths Within 3 Days N = 30	*p*-Value
Duration from start of first to end of last ventilation event, s	134 [49, 318]	61 [41, 159]	325 [208, 379]	<0.01§
Fraction of time from start of first to end of last ventilation event spent on suctioning, stimulation, ventilation, and other resuscitation interventions, %				
Suctioning	0 [0, 11]	0 [0, 12]	4 [0, 11]	0.55§
Stimulation	11 [0, 26]	8 [0, 26]	12 [6, 23]	0.33§
Ventilation	61 [40, 81]	55 [32, 87]	66 [50, 80]	0.30§
Other resuscitation interventions	0 [0, 0]	0 [0, 0]	0 [0, 0]	0.061§

Note. HBB = Helping Babies Breathe; s = seconds; n = number.
* Missing data for seven babies; four surviving, 3 deaths.
† Missing data for two babies; one surviving, 1 death.
‡ Resuscitation ended before one minute after initiation of ventilation for two babies; one survivor, 1 death.
§ Mann−Whitney *U* test.
‖ Pearson chi-square test.
¶ Fisher's exact test.

achieved in 59/76 videos (78%). Annotation agreement was <80% for 17/76 videos (22%). Each episode of "disagreement" was reviewed and discussed by the whole group, and consensus agreed upon. The group's annotation was used for analysis. Each episode where the view was obscured (n = 8) was also reviewed by the group. If interventions could not be clearly seen to have occurred or not, this was noted. After completion of annotations and agreement in all episodes, reviewers were unblinded to outcomes, heart rate, ventilation, and observational data.

In addition to the resuscitation interventions, the following teamwork characteristics were annotated by one observer (I.H.); time with more than one provider present (visible in video), number of providers involved in the resuscitation, handovers between providers during an intervention, and conflicts (providers acting against each other's interventions). One example of a resuscitation timeline is shown in Figure 4.

Statistical Analysis

Analysis was performed by IBM SPSS Statistics Version 25. Data are displayed as medians [IQR] unless otherwise stated. Subgroups (survivors vs. deaths within 3 days) were compared using Mann−Whitney *U* test for continuous data and Pearson chi-square or Fisher's exact test for categorical data.

Ethical Clearance

The study was approved by the National Institute for Medical Research in Tanzania (Ref. NIMR/HQ/R.8a/Vol.IX/1434 and NIMR/HQ/R.8c/Vol. I/312) and The Regional Committee for Medical and Health Research Ethics in Norway (Ref. 2013/110). All providers were informed and gave consent. Mothers were informed about the study, but consent was not deemed necessary since this was a quality assessment study.

Results

During the study period, 12,803 newborns were born at HLH; of these, 346 were stillbirths. Among the 12,457 liveborns, 921 (7.0%) were ventilated. Labor characteristics and condition at birth for the 76 included newborns are presented in Table 1.

In 48 (63%) of the analyzed resuscitations, the main provider was a nurse-midwife. In the remaining 28 resuscitations, main providers were 16 anesthetic nurses, six operating nurses, and five doctors (missing data for one resuscitation).

Resuscitation Interventions

Resuscitation characteristics and interventions are presented in Table 2. The median time from birth to placement

Table 3 Teamwork Characteristics

Teamwork Characteristics	All Newborns N = 76	Survivors N = 46	Deaths Within 3 Days N = 30	*p*-Value
Providers available and involved in resuscitation				
Number of episodes with more than one provider available, n (%)	73/76 (96)	43/46 (93)	30/30 (100)	0.27§
Fraction of time with more than one provider available, %	81 [68, 97]	76 [52, 94]	91 [71, 98]	0.047†
Number of episodes with more than one provider involved in resuscitation, n (%)	72/76 (95)	42/46 (91)	30/30 (100)	0.15§
Fraction of time with more than one provider involved in resuscitation, %	38 [18, 57]	28 [8, 46]	49 [28, 66]	<0.01†
Handover between providers during an intervention				
Number of episodes with handovers between providers during an intervention, n (%)	33/72 (46)	17/42 (40)	16/30 (53)	0.28‡
Number of episodes with handover between providers during suctioning, n (%)	9/72 (13)	6/42 (14)	3/30 (10)	0.73§
Number of episodes with handover between providers during stimulation, n (%)	3/72 (4)	3/42 (7)	0/30 (0)	0.26§
Number of episodes with handover between providers during ventilation, n (%)	24/72 (33)	10/42 (24)	14/30 (47)	0.076§
Conflicts between providers				
Number of episodes with conflicts, n (%)	7/72 (10)	5/42 (12)	2/30 (7)	0.69§
Number of episodes with covering conflicts*, n (%)	5/72 (7)	4/42 (10)	1/30 (3)	0.39§
Number of episodes with conflicts in suctioning vs. ventilation, n (%)	2/72 (3)	1/42 (2)	1/30 (3)	1.00§

Note. n = number.
* One provider covering and another uncovering the newborn.
† Mann-Whitney U Test.
‡ Pearson Chi-square.
§ Fisher's Exact Test.

on the resuscitation table was 59 seconds. Most newborns were both suctioned and stimulated repeatedly on the resuscitation table before the first ventilation, at a total of median 22 and 23 seconds, respectively. Ventilation was initiated within one minute after birth in 15% of the resuscitations, and median time from birth to first ventilation was 108 seconds. The first ventilation event was paused after median 9 seconds, followed by a pause of 8 seconds before ventilations restarted. Figure 2B illustrates different time points for interventions and how they deviate from the HBB guideline.

There were few observed differences in treatment between survivors and those who died (Tables 2 and 3). The resuscitation lasted longer, more time was spent on ventilation, and more than one provider was more often involved among newborns who died versus those who survived. Conversely, more time was spent on stimulation among survivors.

Teamwork

Most of the episodes (95%) had sequences with two or more providers actively involved in the resuscitation at the same time. Handovers between providers occurred during interventions in 46%, and conflicts between providers were observed in 10% of the episodes. Teamwork characteristics and provider involvement are presented in Tables 3 and 4.

Discussion

In this study, we analyzed the workflow of 76 real newborn resuscitations, in a resource-limited setting with regular in situ HBB simulation training over several years. We found that practice during actual newborn resuscitations was not consistent with the intention of the HBB training, targeting current international guidelines for newborn resuscitation. Start of ventilation was commonly delayed, and ventilation interrupted, with more time than recommended spent on stimulation and suction. However, few differences in resuscitation practice were observed among newborns who survived versus those who died. Several nurse-midwives worked together during newborn resuscitations in this rural setting, contrary to what is often believed.

"The Golden Minute" is a key target during HBB training; however, most of the studied newborns were not ventilated within one minute after birth. HBB states that cord-cut should not delay start of ventilation but also recommends that the facility's routine for cord-cut should be followed. At HLH, like most other places, newborns must

Table 4 Maximum Number of Providers Involved in Resuscitation and Time of Involvement

	Maximum Number of Providers Involved During Resuscitation			
Provider Involvement	1 n = 4	2 n = 49	3 n = 21	4 n = 2
Fraction of time with 1 provider involved, %	100	75 [53, 88]	49 [34, 58]	19 [18, 20]
Fraction of time with 2 providers involved, %		25 [12, 47]	44 [36, 55]	51 [41, 61]
Fraction of time with 3 providers involved, %			7 [4, 10]	29 [21, 38]
Fraction of time with 4 providers involved, %				1 [0, 2]

Note. n = number.

be moved to a resuscitation table before ventilation can start. As the cord-cutting procedure may take up to 30 seconds in this setting, starting ventilation within ''The Golden Minute'' is challenging unless the newborn is resuscitated by the mother with intact cord. In addition, before initiation of ventilation, most newborns in our study were both suctioned and stimulated longer than recommended by HBB, and with repeated events, as opposed to HBB describing these as single time events (Figure 2A). A previous study from Tanzania documents that the risk of death or prolonged admission increases 16% for every 30 seconds delay in starting ventilation (Ersdal, Mduma, Svensen, & Perlman, 2012). The same study reported that half of the nonbreathing newborns would initiate spontaneous breathing after stimulation and/or suctioning alone. Uncertainty related to immediate assessment of the newborns' condition and whether a newborn will respond to stimulation by breathing may be another reason for delaying start of ventilation (Moshiro et al., 2018b).

Once initiated, ventilation should continue until the newborn is breathing well, according to HBB. In this study, we found that the first ventilation event typically lasted less than 10 seconds. In almost one third of the episodes where ventilation was interrupted, no obvious reason for the pause was identified. In another third of the episodes, stimulation was identified as the reason for the pause. In a recent study from Norway, interrupted ventilation was commonly observed, especially for newborns who unexpectedly needed resuscitation (Skåre et al., 2016). The qualitative study from HLH identified anxiety and difficulties in assessing clinical responses during ventilation as barriers to effective ventilation. Improved teamwork and frequent ventilation training were suggested to facilitate better resuscitation performance (Moshiro et al., 2018b).

In our study, we found that nurse-midwives worked together in a team during most newborn resuscitations. More teamwork was observed in the episodes where newborns died within three days, compared to survivors. This indicates that the nurse-midwives called for help and supported each other when needed. Furthermore, few differences in resuscitation practice were observed between those who survived and died, indicating that the nurse-midwives were able to provide the same care even in more stressful situations. Thus, the differences in final outcome seem to be not related to systematic differences in care, but rather associated with the newborn's condition at birth, as reported in previous studies (Linde et al., 2017; Moshiro et al., 2018a).

HBB emphasizes to keep the newborn warm, by drying and covering the head and the body. A recent study from Tanzania reported low temperature to be strongly associated with early neonatal deaths (Moshiro et al., 2018a). Common practice at HLH is to wrap the newborn in a dry blanket before moving to the resuscitation table. In the video analysis, we observed that the newborns were fully uncovered almost one third of the episode time. A reason for uncovering the baby may be to look for chest-rise during ventilation or for spontaneous breathing.

In general, the results show that even for nurse-midwives working in a setting with regular and frequent simulation training over several years, it may still be a challenge to treat newborns according to guidelines. There may be several reasons for this. First, we speculate that prior experiences may have led to behaviors that are difficult to change without specific focus during training. Suctioning was previously recommended for all newborns and becomes an example from this study on a learned behavior that seems difficult to change. In 2006, the Neonatal Resuscitation Program emphasized that suctioning was no longer recommended for all newborns directly after birth (Kattwinkel, 2006). The current recommendation by HBB is to suction only if secretions are blocking the mouth or nose or if there is meconium in the amniotic fluid. In our study, suction was done in 89% of the resuscitations, and 61% of the newborns were suctioned before initiation of ventilation. Only half of these had amniotic fluid stained with meconium or blood. There may have been other indications for suctioning that were not visible on the videos, but it is also likely that many newborns were suctioned without adequate indication. A previous observational study from Nepal also reported excessive suctioning as a deviation from resuscitation guidelines after regular HBB training (Lindbäck et al., 2014).

According to Kolb's learning theory, learning happens through transformation of experience (Figure 1), and learners have to go through all four phases for the learning to be effective (Stocker et al., 2014). We speculate that all phases have not been actively applied in the regular HBB trainings at HLH. The experience phase, with active simulation using the newborn simulator, has been dominant in the low-dose high-frequency trainings. Lack of facilitated debriefings with reflection and conceptualization may have limited the active experimentation of new knowledge and led to suboptimal learning. Including all the phases from Kolb's learning cycle into HBB simulation trainings would likely increase learning and improve translation of new knowledge and skills into clinical practice. Further studies should be done to investigate how this model can be used to facilitate continuous learning from the nurse-midwives' daily clinical practice. The gaps identified between intended HBB training and clinical practice in this study are related to decision making based on the newborn's responses to different interventions, which can be difficult to address in simulation training. Clinical debriefings with guided reflection can probably be an important addition to simulation training to improve, apply, and sustain skills. To optimize the workflow, it may be beneficial to also include team training, with more attention to teamwork and roles during newborn resuscitation, especially in hospitals with more than one nurse-midwife on duty.

A major strength of this study is the combination of observational data collected by research assistants, not engaged in clinical care, with data from the Newborn Resuscitation Monitor and video recordings. This made it possible to obtain a unique overview of actual workflow during newborn resuscitations. The video analyses were done by two independent reviewers, with clinical and technical backgrounds, following an iteratively refined annotation protocol. There are limitations to this study. First, we were not allowed to follow each provider individually by the ethical committee, only the profession of the providers. Therefore, training and clinical practice could not be reported on an individual basis. Second, the video recordings started on the resuscitation table, with limited information of the period from birth to table, for example, stimulation and suction. Finally, this is a single-site observational study, which limits generalizability.

Conclusion

This study describes workflow during real newborn resuscitations, performed by nurse-midwives in a rural Tanzanian hospital with regular low-dose high-frequency HBB simulation training over several years. Documented newborn resuscitation practice deviated from HBB guideline and training intention, with delayed and interrupted ventilations, and more stimulation and suctioning than recommended. There were few observed differences between the treatment of the newborns who survived versus those who died. Several nurse-midwives worked together in most of the resuscitations, with handovers during interventions and occasional conflicts in approaches to newborn resuscitation.

To facilitate continuous learning among nurse-midwives and translation to clinical practice, further studies should investigate how clinical debriefing with guided reflection can be used in combination with frequent HBB simulation training. To close the gaps between HBB intention and observed clinical practice, both skill training and team training should focus more on the urgency in decision making leading to start of continuous ventilation within one minute after birth for nonbreathing newborns, to improve patient safety. This is important as HBB simulation training is being rolled-out worldwide.

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