Safer Births - Reference number 2013/110/REK Vest - End report

Safer Births (www.saferbirths.com)

A research, development and implementation project to improve fetal heart rate monitoring, newborn resuscitation and perinatal outcomes worldwide. The project has developed new innovative products and training methods to better equip and train healthcare workers and is establishing new knowledge related to birth. Data-collection has taken place at four study sites/hospitals in Tanzania from 2013-2018.

Applications to REK Vest

1) 2013 Main application - approved
2) 2016 Amendment: expansion to 4 sites/hospitals and deferred oral consent – approved
3) 2017 Amendment: expansion of data collection period through 2018 – approved

Collaborating Institutions

Safer Births is a collaboration between several Tanzanian institutions, Stavanger University Hospital, SAFER, Laerdal Global Health, Laerdal Medicals, Weill Cornell Medical College, University of Stavanger, University of Oslo, Norwegian Institute of Public Health, The Arctic University of Norway, University of Bergen, and Trinity College.

Size/funding

The project has an overall budget (including in-kind contributions) of approximately 100 million NOK with around 100 researchers/research staff and engineers. It is a multidisciplinary team-work involving neonatology, obstetrics, nursing, psychology/ pedagogics, mathematics, statistics, physics, human factors and engineering, amongst others. The project includes 11 PhD fellows, 13 Master students, and around 25 supervisors with a PhD. It was funded by Globvac - the Norwegian Research Council, The Laerdal Foundation, Saving Lives at Birth Grand Challenge, The Southern and Eastern Regional Health Trust, Stavanger University Hospital, Vision 2030 (Innovasjon Norge), SkatteFunn, and Laerdal Global Health (not-for-profit).

Background and Objectives

Globally, almost 3 million newborns die, and another 2.6 million stillbirths occur annually. Approximately 45% of the under 5-year child mortality are due to newborn deaths, often as a consequence of labor complications (birth asphyxia) and sub-optimal newborn care. Furthermore, 99% of stillbirths and newborn deaths occur in low- and middle-income countries. However, studies suggest that the majority of these deaths are preventable with appropriate, low-tech, affordable and easy-to-use tools and technologies coupled with simple training programs. In 2010-2012, the Helping Babies Breathe (HBB) educational program led to a 47% reduction in early newborn mortality and a 24% reduction in fresh stillbirths at 8 study sites in Tanzania.[1] However, 60-80% of the remaining mortality was still related to birth asphyxia.[2] HBB course evaluations found that those who died often had fetal heart rate abnormalities,[3] delayed start of bag-mask ventilation,[4] and a need for prolonged bag-mask ventilation.[4] Adequate fetal heart rate monitoring could prevent fresh stillbirths and birth asphyxia, but is difficult when the patient midwife ratio is high.[3] Furthermore, correct bag-mask ventilation is difficult to learn and a one-day HBB course did not facilitate transfer of skills and knowledge to clinical practice.[5] However, additional short and frequent training sessions in the labour room did improve clinical management and early newborn outcomes.[6] Costs per life year gained were US$ 4.21 and costs per life saved were US$ 233 in a rural setting.[7] In 2012, Safer Births was initiated as a collaboration between Stavanger University Hospital, Laerdal Global Health (a not-for-profit company established in 2010) and SAFER to help train and equip birth attendants worldwide and save newborn lives.

Objectives of the Safer Births project

Overarching objective

To develop new knowledge and new innovative products to better equip and increase competence of health care workers for safer births and increased newborn survival worldwide

Secondary main objectives

1. To investigate the normal cardio-respiratory adaption at birth (from intrauterine to extra uterine life)
2. To describe applied bag-mask ventilation (as it relates to flow, volume, pressure) and distal effects (expired CO_2, and newborn heart rate) as it relates to newborn outcome
3. To investigate the consequences of fetal heart rate abnormalities (i.e. intrapartum-related hypoxia) and appropriate interventions to prevent/reverse this process

Methodology

All necessary scientific registrations, approvals, and certificates were obtained before start of the project and each sub-study and before submission of each manuscript. All devices were CE certified (CE) and tested for compliance with the requirements of the EU Medical Device Directive and appropriate standards for electrical safety and performance. All devices were pre-clinically tested and approved according to Norwegian and Tanzanian rules.

The timeline for data collection was March 2013 through October 2018. Four hospitals were involved: Haydom, Muhimbili, Temeke, and Dongobesh. All sub-studies and analyses were conducted according to protocols. Relevant health care workers were regularly trained and informed about the different sub-studies. Written and/or verbal consent were obtained as approved by the ethical committees (NIMR in Tanzania and REK). All patients were informed about the ongoing studies, and written, verbal and/or no consent were obtained as approved by the ethical committees. Data collection, management, transfer, processing, and storage were done according to standard operating procedures and protocols.

Safer Births consisted of four parts:

1. A descriptive/analytic observational cohort study using an automatic fetal heart rate monitor (Fig. 1) and a resuscitation monitor (Fig. 2) to capture and store biomedical signal data during labor and extending through neonatal cardio-respiratory adaption and resuscitation (Illustration 1)
2. Training interventions and development of new training strategies and equipment to narrow knowledge/skills gaps identified in clinical practice (Illustration 1)
3. Randomized controlled trials (RCT) comparing different equipment for fetal heart rate assessments during labor and different methods of bag-mask ventilation application
4. Quantitative and qualitative evaluations of feasibility, acceptability, and user-friendliness of the different equipment

Fig 1. Fetal heart rate Monitor (Moyo)

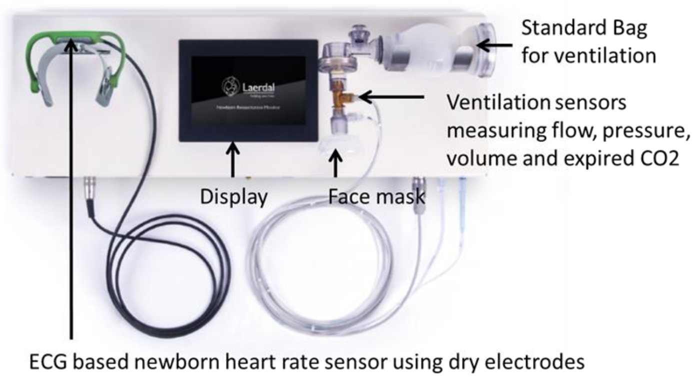

Fig 2. Newborn Resuscitaiton Monitor

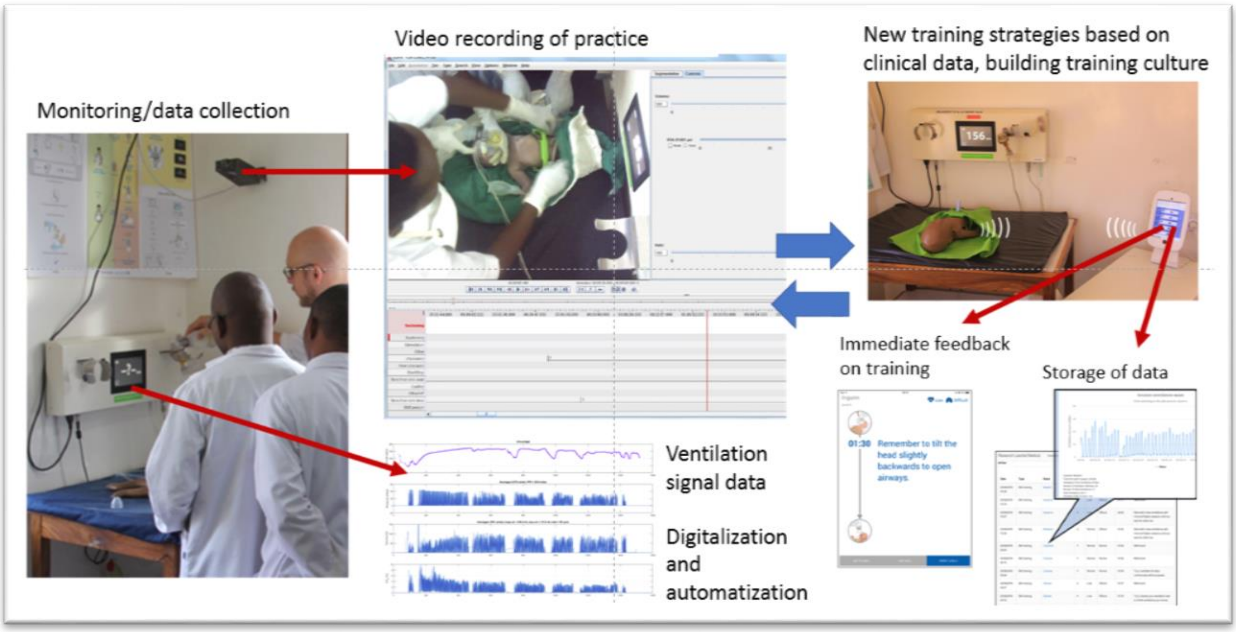

Illustration 1. Collection of signal + video + observational data → Individualized training and feedback based on clinical performance → Digitalization + automatization → Machine learning + artificial intelligence

The following research equipment were used:

- The Pinard fetal stethoscope (Fig. 3)
- A wind-up handheld Doppler for intermittent fetal heart rate detection (Freeplay, Fig. 4)
- Laerdal Fetal Heart Rate Monitor (Moyo, Fig. 1) to strap on the abdomen of women in labor. The device recorded and stored fetal heart rate tracings for subsequent analysis
- Laerdal Newborn Resuscitation Monitor (Fig. 2) to measure, synchronize, and store newborn heart rate and ventilation signals for subsequent analysis, and display the newborn heart rate
- Laerdal Neonatal Resuscitator (standard bag-mask in use today)
- Laerdal Upright Resuscitator
- Laerdal Upright Resuscitator with PEEP (Positive End Expiratory Pressure) valve (Fig. 5)

Fig. 5. Upright with PEEP

Results and Discussion

Related to the overarching objective

Several innovative products for training and treatment are developed. Our main partner in Tanzania, Haydom Lutheran Hospital, has seen a significant reduction in perinatal mortality during the project period. Statistical process controls methods (i.e. variable life-adjusted and cumulative sum plots) reveal a steady improvement in perinatal survival during the period.[8] Implementation of the HBB program and different Safer Births interventions/equipment can be linked to the increased perinatal survival.[8] After adjusting for risk-factors among the delivering women over time, the extra number of newborns saved is 250.[9] Increased newborn survival worldwide should be possible with a combination of HBB and available Safer Births products for treatment and training, supported by new published knowledge and updated international guidelines[10-12] as a basis for local, national, and regional implementation programs.[13-17]

Related to the secondary objectives

The normal cardio-respiratory adaption at birth

With the new dry-electrode heart rate sensor it has for the first time been possible to record immediate newborn heart rate at birth. The heart rate is increasing from 120-150 beats/minute during the first 45 seconds after birth, stabilizing around 155 beats/minute at 2 minutes.[18] Median time to start spontaneous breathing is 5 seconds from birth and >90% of those who start breathing without interventions, will start before 30 seconds after birth.[4] Among 12 800 normal/healthy newborns, the risk of death/admission decreased by 20% for every 10-second delay in cord clamping after start of breathing.[19]

The applied bag-mask ventilation and distal effects as it relates to newborn outcome

In the study period (March 1st 2013 to October 31st 2018) at Haydom hospital, 22 199 consecutive deliveries were observed and recorded, 1657 apneic newborns were bag-mask ventilated, and the newborn resuscitation monitor was used in 1582 cases. These data have served as a basis for several descriptive sub-studies and analyses, e.g. to describe the abnormal transition from intra- to extrauterine life and characteristics and effects of bag-mask ventilation.[20-30] Specifically, our research document that the progression to fresh stillbirth or a

severely asphyxiated newborn is likely part of the same intrapartum hypoxic circulatory end-process.[20] Distinguishing fresh stillbirths from severely asphyxiated newborns is clinically difficult and probably influences estimated global perinatal mortality rates.[20] During newborn bag-mask ventilation (without PEEP), higher than expected/recommended tidal volumes lead to a rapid increase in newborn heart rate,[21] which is also beneficial for neonatal outcome.[22,23] Newborn heart rate and delivered tidal volume (and continuous ventilation) are therefore important predictors of newborn outcomes, and newborn heart rate was appreciated by the midwives as a useful feedback during resuscitation.[24]
The optimal timing of cord clamping in non-breathing newborns in need of resuscitation remains unclear. We failed to demonstrate a relationship between time to cord clamping and onset of breathing (after stimulation/suction) or initiation of ventilation and 24-hour outcomes.[25] However, there is a significant increase in risk of death/admission (12%-16%) for every 30-second delay in initiation of bag-mask ventilation.[4,25]
Presumed causes of death (within 7 days after birth) among admitted newborns at Haydom were birth asphyxia (60%), prematurity (15%), sepsis (15%) and congenital abnormalities (11%).[2,26] Hypothermia (<36 degree Celsius) on admission is very common both in survivors and deaths, and a major contributor to morbidity and mortality.[26,27]

Resuscitating a non-breathing newborn is perceived as very stressful, and frequent ventilation training and "being prepared" were reported as critical factors to improve clinical practice.[24] The Upright Resuscitator (Fig. 5) was designed with and without a PEEP function. Both devices were tested in pre-clinical studies using the newborn simulator, NeoNatalie (Fig 6), before being introduced in two consecutive RCTs at Haydom hospital. The Upright Resuscitator was more easily handled and accepted by untrained personnel, compared to the standard resuscitator,[28] and they managed to provide adequate PEEP.[29] In real newborn resuscitations, the use of Upright resuscitators without PEEP-valve as compared to standard resuscitators, resulted in delivery of slightly increased tidal volumes,[30] which again is needed for a more rapid increase in newborn heart rate and better outcomes.[21-23] More babies were classified as normal 30 minutes after birth if ventilated with Upright, as compared to standard resuscitator.[30] Data from the second RCT at Haydom (rural site), comparing Upright Resuscitators with and without PEEP-valves, is still under analysis. The planned RCT at Muhimbili (urban site) comparing Upright Resuscitators with and without PEEP-valves was not feasible to conduct.


Fig 6. NeoNatalie and the Newborn Ventilation Trainer

Several descriptive studies are in progress, investigating the predicative value of end-expiratory CO_2 levels and association to outcome, importance of gasping, establishment of functional residual capacity during initial ventilation, lung compliance during ventilation, use of PEEP in real resuscitations, newborn heart rate distribution and changes during ventilation, ECG-signals in fresh stillbirths, reliability of Apgar scoring, effects of suctioning, head positions and hand-grips during ventilation, newborn resuscitation guideline (HBB) adherence in clinical practice, and finally effects of trainings on clinical practice and newborn outcomes.

The Newborn Resuscitation Monitor (Fig. 2) was tested on piglets before being introduced in clinical care and research at Haydom hospital.[31] The collected biomedical signal data (ventilation, ECG/heart rate, and acceleration) and the video data have been utilized by the biomedical data analysis group at the University of Stavanger to develop automatic algorithms for extensive analyses and interpretation of all the data.[32-41] Exploratory analyses of ventilation signals and changes in heart rate signals,[32,33] automatic detection and parameterization of ventilation signals,[34] the relationship between characteristics of ventilation performance and newborn responses,[35] and a state transition model of complex monitored health data,[36] have been published. Furthermore, detection (and thereby more accurate investigation) of certain clinical activities (like stimulation and suctioning) based on the acceleration signal (in the ECG/heart rate sensor) is possible.[37-40] Finally, algorithms for automatic object detection on the videos have been developed.[41] This is the first step to further improve studies of the videos as a supplement to other recorded data and/or to answer several specific research questions related to clinical performance and quality of care.

Fig 7. NeoBeat

The collected data have been used to develop the Laerdal Newborn Ventilation Trainer (Fig. 6) and the NeoBeat newborn heart rate meter (Fig. 7). The above described signal data in combination with observed process/management and patient outcome data will be used to develop machine learning and artificial intelligence programs to further improve these training and treatment devices and learning/feedback strategies (Illustration 1).

To investigate the consequences of fetal heart rate abnormalities and appropriate interventions to prevent/reverse this process

Fetal heart rate abnormalities are strongly associated with fresh stillbirths and birth asphyxia.[3,20,22,23,26,41] Fetal heart rate abnormalities were associated with a 2-fold and 3-fold increased risk of newborn death within the first 24 hours and 7 days, respectively.[22,23] Strategies to improve fetal heart rate monitoring to facilitate awareness of fetal distress, decision-making and timely obstetric actions are urgently needed.


Fig 3. Pinard

At the rural site, Haydom Hospital, an RCT comparing intermittent intrapartum fetal hart rate monitoring using the fetal stethoscope (Pinard, Fig. 3) versus the wind-up hand-held Doppler (Freeplay, Fig. 4) was conducted. No significant differences were found in abnormal fetal heart rate detections (3.1% versus 4.2%) and perinatal adverse outcomes (2.5% versus 2.4%).[42] The midwives at Haydom expressed that they were used to the fetal stethoscope and their preferences were influenced by training, experience, perceived reliability of a device, and convenience to use.[43] Therefore, in the subsequent RCT, testing the use of Moyo (Fig. 1), Pinard was selected as the control arm, and abnormal fetal heart rate was detected much more frequently in the Moyo arm compared to the Pinard arm (8.1% versus 3.0%).[44] Intrauterine resuscitation and cesarean section were performed more often in the Moyo arm, with a non-significant trend towards better perinatal outcomes,

Fig 4. Freeplay

compared to the Pinard arm.[44] Data from the before-after implementation of Moyo at the rural district hospital, Dongobesh, is still under analysis.

At one urban site in Dar es Salaam, another RCT comparing intermittent intrapartum fetal heart rate monitoring using the fetal stethoscope (Pinard, Fig. 3) versus the wind-up hand-held Doppler (Freeplay, Fig. 4) was conducted at Muhimbili National Hospital. The use of Doppler lead to more abnormal fetal heart rate detections (6.0% versus 3.9%) and better perinatal outcomes among vaginally delivered newborns with detected abnormal fetal heart rate.[45]

The new strap-on fetal heart rate monitor for automatic/continuous monitoring (Moyo, Fig. 1) was first introduced at Temeke District Hospital in the suburb of Dar es Salaam in a before-after implementation study. Implementation of Moyo improved midwifery practice; there were lower rates of non-assessment/documentation of fetal heart rate after (2.2%) versus before (45.7%) implementation, more detection of abnormal fetal heart rates after (8.0%) versus before (1.6%), more and timelier obstetric responses and cesarean sections, and reduced number of newborns in need of resuscitation, compared to intermittent assessments using Pinard.[46] A subsequent RCT testing Moyo versus hand-held Doppler was finally conducted at Muhimbili.[47] Fetal heart rate abnormalities were detected more often in the Moyo arm (13.3% versus 9.8%), these were detected earlier, but time from detection to delivery was longer.[47] Studies powered to detect differences in perinatal outcomes with timely responses are recommended.

Qualitative studies from Dar es Salaam reveal that the use of Moyo positively affected the mothers' birth experience, providing much needed reassurance of the wellbeing of the child and increased communication and attention from the midwives.[48] Midwives experienced the Moyo training as useful, but asked for additional training in basic labour monitoring and management.[49] The high turn-over of staff was mentioned as a huge challenge, since trained personnel were leaving, revealing the need for frequent training sessions.[49] However, the midwives perceived Moyo as useful, improving the care, and making it possible to adequately monitor several laboring women at the same time and to react faster.[50] They expressed a fear of being blamed for negative fetal outcomes and a lack of clarity about when Moyo should be used in a continuous manner.[50]

Overall, fetal heart rate recordings using Moyo (Fig. 1) were collected from 3711 deliveries at Muhimbili, Temeke and Haydom hospitals. There are ongoing exploratory analyses of this signal data to better understand different fetal heart rate patterns, alarm settings, and optimal frequencies of intermittent assessments in different stages of labour in relationship to perinatal outcomes.

Further data analysis/use, security, storage, and timelines

Raw data will be securely stored in locked cabinets at the different study sites in Tanzania for 5 years. De-identified (pseudonymised) copies of electronic databases, video-data, and processed biomedical signal data will be stored on a safe research server under the governance and responsibility of Stavanger University Hospital and the Principal Investigator

Hege Ersdal. There are still several complex hypotheses, research questions, and digital/technological innovations that are possible to explore/develop using a combination of the different data-sets. Therefore, we would like to store the data for 10 years – through 2028. A data risk assessment according to the new GDPR legislation has already been undertaken.

References

1) Msemo G, Massawe A, Mmbando D, Mwizamuholya D, Ersdal HL, Perlman J. Newborn Mortality and Fresh Stillbirth Rates in Tanzania After Helping Babies Breathe Training. Pediatrics 2013; 131: 353-60

2) Ersdal HL, Mduma E, Svensen E, Perlman JM. Birth Asphyxia: A Major Cause of Early Neonatal Mortality in a Tanzanian Rural Hospital. Pediatrics 2012;129:1238-43.

3) Ersdal HL, Mduma E, Svensen E, Sundby J, Perlman JM. Intermittent Detection of Fetal Heart Rate Abnormalities Identify Infants at Greatest Risk for Fresh Stillbirths, Birth Asphyxia, Neonatal Resuscitation, and Early Neonatal Deaths in a Resource Limited Setting. Neonatology 2012;102:235-42

4) Ersdal HL, Mduma E, Svensen E, Perlman JM. Early initiation of basic resuscitation interventions including face mask ventilation may reduce birth asphyxia related mortality in low-income countries. Resuscitation 2012;83:869-73.

5) Ersdal HL, Vossius C, Bayo E, Mduma E, Perlman JM, Lippert A, Søreide E. A one-day "Helping Babies Breathe" Course Improves Simulated Performance but not Clinical Management of Neonates. Resuscitation 2013;84:1422-1427.

6) Mduma E, Ersdal H, Svensen E, Kidanto H, Auestad B, Perlman J. Frequent brief on-site simulation training and reduction in 24-hour neonatal mortality – an educational intervention study. Resuscitation 2015: 93:1-7

7) Vossius C, Lotto E, Lyanga S, Mduma E, Msemo G, Perlman J, Ersdal HL. Cost-effectiveness of the “Helping Babies Breathe” program in a rural hospital in Tanzania. PLOS One 2014; DOI: 10.1371/journal.pone.0102080.

8) Mduma E, Ersdal H, Kvaløy JT, Svensen E, Mdoe P, Perlman JM, Kidanto H, Søreide E. Using statistical process control methods to trace small changes in perinatal mortality after implementation of training program in a low-resource setting. Int J Qual Health Care 2018;30(4):271-275. doi: 10.1093/intqhc/mzy003

9) Mduma ER, Kvaløy JT, Søreide E, Svensen E, Mdoe P, Perlman J, Johnson C, Kidanto H, Ersdal HL. Frequent Refresher Newborn Resuscitation Training Improves Perinatal Outcome Over time in a rural Tanzanian hospital. Submitted BMJ Open, 2019

10) Wyllie J, Perlman J, Kattwinkel J et al. Part 7: Neonatal Resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation 2015;95:e169-201.

11) Perlman J, Wyllie J, Kattwinkel J et al. Part 7: Neonatal Resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation 2015;132:S204–S241. DOI: 10.1161/CIR.0000000000000276.

12) Perlman J, Wyllie J, Kattwinkel J et al. Part 7: Neonatal Resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations (Reprint). Pediatrics 2015, Volume 136/ISSUE Supplement 2. DOI:10.1542/peds.2015-3373D

13) Perlman J, Msemo G, Ersdal H, Ringia P. Designing and implementing the Helping Babies Breathe program in Tanzania. J Pediatr Intensive Care, Global Health Issue 2017;06(01):028-038. DOI: 10.1055/s-0036-1584674.

14) Ersdal HL, Singhal N. Resuscitation in Resource-limited Settings. Invited Review article. Semin Fetal Neonatal Med. 2013 Dec;18(6):373-8. doi: 10.1016/j.siny.2013.07.001

15) Ersdal H, Singhal N, Msemo G, Ashish KC, Santorino D, Moyo N, Evans C, Smith J, Perlman J, Niermeyer S. Successful implementation of Helping Babies Breathe and Helping Mothers Survive Programs – An Utstein Formula for Newborn and Maternal Survival. PLoS ONE 2017;12(6):e0178073. https://doi.org/10.1371/journal.pone.0178073

16) Kamath-Rayne BD, Berkelhamer SK, Ashish H, Ersdal H, Niermeyer S. Neonatal resuscitation in global health settings – An examination of the past to prepare for the future. Pediatric Research 2017; doi:10.1038/pr.2017.48.

17) Niermeyer S, Robertson NJ, Ersdal H. Beyond basic resuscitation: What are the next steps to improve the outcomes of resuscitation at birth when resources are limited? Semin Fetal Neonatal Med 2018; 23(5):361-368. doi: 10.1016/j.siny.2018.06.002.

18) Linde J, Perlman J, Øymar K, Francis F, Eilevstjønn J, Shultz J, Ersdal H. The normal heart rate in newborns in the first three minutes of life; assessed by a novel ECG monitor. Neonatology, 2016;110:231-237.

19) Ersdal HL, Linde J, Mduma ER, Auestad BH, Perlman J. Neonatal Outcome Following Cord Clamping After Onset of Spontaneous Respiration. Pediatrics 2014; 134:265-72

20) Ersdal H, Eilevstjønn J, Linde J, Yeconia A, Mduma E, Kidanto H, Perlman J. Fresh Stillbirths and Severely Asphyxiated Neonates Represent a Common Hypoxic-ischemic Pathway. Int J Gynaecol Obstet 2018;141:171-180. doi: 10.1002/ijgo.12430.

21) Linde J, Schulz J, Perlman JM, Øymar K, Blacy L, Kidanto H, Ersdal HL. The relation between given volume and heart rate during newborn resuscitation. Resuscitation 2017;117:80-86. DOI: 10.1016/j.resuscitation.2017.06.007

22) Linde J, Perlman J, Øymar K, Schultz J, Eilevstjønn J, Thallinger M, Kusulla S, Kidanto H, Ersdal H. Predictors of 24-hour outcome in newborns needing positive pressure ventilation at birth in a low-resource setting. Resuscitation 2018;129:1-5.

23) Moshiro R, Perlman J, Kidanto H, Kvaloy JT, Mdoe P, Ersdal HL. Newborn Resuscitation in a Rural Tanzanian Hospital: Quality of Positive Pressure Ventilation of Admitted Newborns and Outcome within 7 days. Plos One 2018;13(8): e0202641.
24) Moshiro R, Ersdal H, Kidanto H, Mdoe P, Mbekenga C. Factors affecting effective ventilation during newborn resuscitation: A qualitative study among midwives in rural Tanzania. Global Health Actions 2018; 11(1):1423862. DOI: 10.1080/16549716.2018.1423862.
25) Ersdal H, Linde J, Auestad B, Mduma E, Lyanga S, Svensen E, Perlman J. Cord Clamping in Relation to Breathing or Ventilation among Depressed Infants and 24-hour Outcome – an observational study. BJOG 2016;123:1370-1377.
26) Moshiro R, Perlman J, Kidanto H, Kvaløy JT, Mdoe P, Ersdal HL. Causes of Deaths Among Admitted Newborns Within First 7 Days in a Rural Hospital, Tanzania. Neonatology, Jan 2019, under review
27) Massawe A, Kidanto H, Moshiro R, Majaliwa E, Chacha F, Shayo A, Mdoe P, Ringia P, Azayo M, Msemo G, Mduma E, Ersdal H, Perlman J. A Care Bundle including Antenatal Corticosteroids Reduces Premature Infant Mortality in Tanzania a Low Resource Country. PLoS ONE 2018: 13(3): e0193146. https://doi.org/10.1371/journal.pone.0193146
28) Thallinger M, Ersdal H, Eilevstjønn J, Ombay C, Størdal K. Manikin ventilation comparing new upright neonatal resuscitator to standard equipment. Arch Dis Child Fetal Neonatal 2015;0:F1-F5. DOI:10.1136/archdischild-2015-308754
29) Thallinger M, Ersdal H, Morley C, Purington C, Gomo Ø, Mduma E, Eilevstjønn J, Størdal K. Neonatal bag and mask ventilation on a manikin model with two novel PEEP valves. Arch Dis Child Fetal Neonatal Ed 2016;0:F1-F6
30) Thallinger M, Ersdal H, Francis F, Yeconia A, Mduma E, Kidanto H, Linde JE, Eilevstjønn J, Gunnes N, Størdal K. Born not breathing: A randomised trial comparing two self-inflating bag-masks during newborn resuscitation in Tanzania. Resuscitation 2017;116:66-72.
31) Linde J, Eilevstjønn J, Øymar K, Ersdal H. Feasibility of a prototype Newborn Resuscitation Monitor measuring heart rate and ventilator parameters. BMC Research Notes 2017;10:235. DOI 10.1186/s13104-017-2530-z.
32) Vu H, Eftestøl T, Engan K, Eilevstjønn J, Linde J, Ersdal H. Exploratory Analysis of Ventilation Signals from Resuscitation Data of Newborns. Congress paper, IEEE/CAS-EMB Biomedical Circuits and Systems Conference 2014.
33) Vu H, Eftestøl T, Engan K, Eilevstjønn J, Linde J, Ersdal H. Exploratory Analysis of Heart Rate Changes in Newborns to Investigate the Effectiveness of Bag-Mask Ventilation. Congress paper, The Computing in Cardiology 2014.
34) Vu H, Eftestøl T, Engan K, Eilevstjønn J, Yarrot LB, Linde J, Ersdal H. Automatic Detection and Parameterization of Manual bag-mask ventilation of Newborns. IEEE Journal of Biomedical and Health Informatics 2016; 10.1109/JBHI.2016.2518238.
35) Vu H, Eftestøl T, Engan K, Eilevstjønn J, Yarrot LB, Linde J, Ersdal H. Exploring the relationship between characteristics of ventilation performance and response of newborns during resuscitation. Communications in Computer and Information Science 574, 8th International Joint Conference, BIOSTEC 2015, Springer 2016;p275-290.
36) Schulz J, Kvaløy JT, Engan K, Eftestøl T, Jatosh S, Kidanto H, Ersdal H. State transition modelling of complex monitored health data. Statistics in Medicine, Nov 2018, under review.
37) Vu H, Eftestøl T, Engan K, Eilevstjønn J, Yarrot L, Linde J and Ersdal H. Detection of Activities during Newborn Resuscitation Based on Short-Time Energy of Acceleration Signal. Image and Signal Processing, Volume 9680, Lecture Notes in Computer Science 2016, pp262-270.
38) Vu H, Eftestøl T, Engan K, Jatosh S, Kusulla S, Ersdal H. Automatic classification of resuscitation activities on birth asphyxiated newborns using acceleration and ECG signals. Biomedical Signal Processing and Control 2017;36:20-26.
39) Urdal J, Engan K, Eftestøl T, Yarrot L, Eilevstjønn J, Kidanto H, Ersdal H. Signal Processing and Classification for Identification of Clinically Important Parameters During Neonatal Resuscitation. Congress paper IEEE ICSIPA 2017. 978-1-5090-5559-3/17/$31.00 ©2017 IEEE
40) Meinich-Bache Ø, Engan K, Austvoll I, Eftestøl T, Myklebust H, Blacy L, Kidanto H, Ersdal H. Object Detection During Newborn Resuscitation Activities. IEEE Transactions on Biomedical Engineering 2019, under review
41) Kidanto H, Msemo G, Mmbando D, Rusibamayila N, Ersdal H, Perlman J. Predisposing Factors Associated with Stillbirths in Tanzania- Opportunities for Prevention. Int J Gynaecol Obstet 2015; 130: 70-73
42) Mdoe PF, Ersdal H, Mduma E, Perlman J, Moshiro R, Wangwe P, Kidanto H. Intermittent Fetal Heart Rate Monitoring using Fetoscope or Hand held Doppler in Rural Tanzania: a Randomized Controlled Trial. BMC Pregnancy and Childbirth 2018;18:134.
43) Mdoe P, Ersdal H, Mduma E, Moshiro R, Kidanto H, Mbekenga C. Midwives' perceptions on using a fetoscope and Doppler for fetal heart rate assessments during labor: A qualitative study in rural Tanzania. BMC Pregnancy and Childbirth 2018;18:103. https://doi.org/10.1186/s12884-018-1736-y
44) Mdoe P, Ersdal H, Mduma E, Moshiro R, Dalen I, Perlman J, Hussein K. Fetal heart rate monitoring in a low-resource setting; continuous Doppler versus intermittent fetoscope – A randomized controlled study. Int J Gynaecol Obstet 2018;143(3):344-350. DOI:10.1002/ijgo.12648.
45) Kamala B, Kidanto H, Wangwe P, Dalen I, Mduma E, Perlman J, Ersdal H. Intrapartum fetal heart rate monitoring using a hand-held Doppler versus Pinard stethoscope: A randomized controlled study in Dar es Salaam. International Journal of Women's Health 2018;10:341-48.
46) Kamala B, Hussein K, Dalen I, Abeid MS, Ngarina MM, Perlman J, Ersdal H. Implementation of a Novel Continuous Fetal Doppler (Moyo) Improves Quality of Intrapartum Fetal Heart Rate Monitoring in a Resource-Limited Tertiary Hospital in Tanzania: An Observational Study. Plos One 2018;13(10):e0205698.

47) Kamala BA, Kidanto H, Dalen I, Ngarina MN, Abeid MS, Perlman JM, Ersdal HL. Effectiveness of a novel strap-on automatic Doppler (Moyo) versus intermittent Doppler in intrapartum detection of abnormal foetal heart rate: A randomized controlled study in Tanzania. Int J Environ Res Public Health 2019;16:315. DOI:10.3390/ijerph16030315..
48) Lafontan S, Sundby H, Ersdal H, Abeid M, Kidanto H, Mbekenga C. *I was relieved to know that my baby was safe*: Women´s attitudes using an electronic fetal heart rate monitor during labor in Tanzania. A qualitative study. Int J Environ Res Public Health 2018;15(2):E302. doi: 10.3390/ijerph15020302.
49) Lafontan SR, Kidanto H, Ersdal HL, Mbekenga CK, Sundby J. Perceptions and experiences of skilled birth attendants on using a newly developed strap-on electronic fetal heart rate monitor in Tanzania. BMC Pregnancy and Childbirth, 2018, under review
50) Lafontan SR, Sundby J, Kidanto H, Mbekenga C, Ersdal HL. Acquiring knowledge about the use of a newly developed electronic fetal heart rate monitor: A qualitative study among birth attendants in Tanzania. Int J Environ Res Public Health 2018;15:E2863. doi:10.3390/ijerph15122863.