Original Article

# Does early heart rate detection and continuous monitoring have an impact on neonatal resuscitation in newborns with intact cord? – An observational study

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## Abstract

**Context:** Heart rate (HR) is the most vital parameter to assess hemodynamic transition at birth. ECG is considered a gold standard for HR assessment. New devices with dry electrodes are easy to apply on a wet newborn. However, the utilization of newer technology that captures fast and reliable HR, and its impact on neonate resuscitation are yet to be explored, especially in newborns with intact cords. **Aims:** to detect HR early by dry electrode devices and its impact on neonatal resuscitation. **Settings and Design:** This is an observational study conducted at a tertiary care hospital in India. **Methods and Material:** A portable pulse oximeter, conventional ECG with modified 3 electrodes, and dry electrodes ECG (Neo Beat) were applied to capture HR ECG and $Sp0_2$. First reliable HR and outcomes of neonates were compared. **Statistical Analysis Used:** Median (IQR) was calculated for quantitative data. These were conducted using an updated version of IBM SPSS Statistics 22 software. **Results:** Out of 329 newborns, 24 newborns had their first documented HR of less than 100 bpm, out of which 14 (58%) initiated respiration with initial steps and the rest 10 required resuscitation (42%) in the form of positive pressure ventilation. Among newborns with a first HR of more than 100 bpm, 8 newborns (2.6%) required resuscitation. The median duration to capture the first reliable HR using dry electrodes was 15 sec (IQR 12.7–20 sec), which was much faster than the time required by conventional ECG (37 sec) and pulse oximetry (80 sec). **Conclusions:** First reliable HR can effectively predict the need for neonatal resuscitation. Dry electrode ECG can effectively capture continuous and reliable HR. HR trends can further assist in predicting the need for neonatal resuscitation and the efficacy of neonatal resuscitation.

**Keywords:** Dry electrodes, heart rate, neonatal resuscitation

## Introduction

Globally, Perinatal asphyxia accounts for 15%–20% of all neonatal deaths, and 25% of all the survivors present with neurologic deficits.[1] In the developing world, the incidence of perinatal asphyxia is 10 times higher as compared to the developed countries; hence, the critical need to develop a proper resuscitation protocol to be implemented at the time of birth in India. Most healthy newborns initiate and establish spontaneous respiration within 30 sec after birth. Approximately, 10% would require assistance in the form of drying and stimulation, 3% would require positive pressure ventilation (PPV), 2% would require intubation, and only 0.1% would require chest compression.[2]

Birth is a smooth transition for the newborn to switch from umbilical circulation to pulmonary circulation and is related to establishing proper ventilation of the lungs. Early cord clamping,

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especially in those newborns, who remain apneic and hypoxic, decreases the left ventricular output because of increased afterload, and at the same time, decreases the preload by limiting the umbilical venous flow to the neonatal heart, compounding the cardiovascular instability and hypoxic insults. Delayed cord clamping (DCC) is beneficial to both term and preterm infants and should be a part of the standard resuscitation protocol.[3,4] Although the duration of delay varies from country to country, the optimal timing of cord clamping is yet to be defined.[5]

A recent study has demonstrated that DCC till placental delivery helps in the delivery of significantly more oxygen to the babies in the initial minutes after birth.[6] Thus, fixed-timed cord clamping does not consider the time variability of establishing spontaneous breathing and the individual variability in switching to pulmonary circulation or delayed adaptation. Physiological cord clamping is cutting the cord either after a newborn's respiration is established in the labour room or cutting the cord after the placenta is delivered.

Infant HR is the most vital parameter used to assess hemodynamic transition at birth and acts as a primary key measure of the adequacy of postnatal transition.[7] American Academy of Pediatric 2015 and International Liaison Committee on Resuscitation 2020 have further reiterated that HR is the most critical parameter during newborn resuscitation.[8] However, available literature suggests that assessing HR clinically, i.e., auscultation and palpation of the umbilical cord, can be unreliable.[9,10] Studies have also shown that pulse oximetry tends to underestimate the infant's HR in the initial minutes after birth and would have led to potentially unnecessary interventions.[11] Therefore, estimating a fast, reliable, and precise HR during the initial minutes of life is crucial. ECG is considered a gold standard technique for HR assessment, which is more reliable and accurate in displaying HR as compared to auscultation and pulse oximetry. Kibsgaard *et al.* demonstrated that nearly 2/3 of infants requiring resuscitation had their first reliable HR of more than 100 bpm, but subsequently, the HR dropped to less than 100.[12] Therefore, continuous monitoring of HR may be more informative than a single reading to determine resuscitation needs and monitor the efficacy of resuscitation.

Routine, conventional ECG in the labour room has its challenges, especially in the application. ECG and pulse oximeter showed a latency period of 24 and 48 sec on pulse oximetry.[13,14]

To overcome this delay, new techniques such as dry-electrode ECG were used, which had both reliable continuous ECG recording within 30 sec and also easy to apply on a wet newborn.[15] This is very important as children would be in secondary apnea and would not respond to drying and stimulation thus, PPV may be started early in these newborns i.e., within 45 sec; However, some children who are apneic, but their HR is more than 100 and increasing we could wait for another 15–30 sec, especially those having delayed adaptation in establishing spontaneous breathing.

However, the utilization of newer technology that captures fast and reliable HR, and its impact on neonate resuscitation are yet to be explored, especially in newborns with intact cords.

## Subjects and Methods

### Study design

This pilot observational study was conducted at the Department of Neonatology at a tertiary care center in Northern India. Inclusion criteria: All newborns born in the Institute during the study period were enrolled after informed consent. Exclusion criteria: Mother who opted out of research and denied consent for participation.

### Equipment and data collection

Currently, as a part of the departmental protocol to improve newborn resuscitation, a portable pulse oximeter (Masimo RD SET Neo with Masimo safety Net software for data extraction), conventional ECG with modified 3 electrodes (IntelliVue Phillips X2 monitor with IntelliVue XDS software), and dry electrodes ECG (Neo Beat: Newborn Heart Rate Meter; Laerdal Medical with "Liveborn" software) are applied routinely to capture the ECG, HR, and all the initial events and steps taken during resuscitation of the newborn.

As per unit protocol, all neonates were received in pre-warn linen, placed over the mother's abdomen (immediate skin-to-skin contact) in the prone position, the head was turned to one side, and quick removal of the wet linen was done. A dry electrode ECG device (Neobeat) and conventional modified 3 electrodes (pre-formed 3-lead ECG) were immediately placed over the upper back simultaneously [Supplementary Material Figure A]. A saturation probe of the pulse oximeter was immediately attached by another nursing officer over the right wrist/hand to capture the earliest preductal oxygen saturation and HR with proper plethysmograph reading. First HR, $SPO_2$, time of placental delivery, time taken to establish spontaneous respiration, time of cord clamping, time of Pitocin administration, time of PPV, and duration of PPV were recorded continuously for the first 10 min after delivery by a different research officer using Liveborn software. All the babies were resuscitated as per standard Neonatal Resuscitation Program guidelines 2020, even if a reliable HR was available within 10 sec and uninterrupted monitoring of ECG and HR was conducted in the first 10 min, irrespective of the need for active resuscitation.

After birth, neonates who required resuscitation were shifted from the mother's abdomen to a specially designed trolley for intact resuscitation [Supplementary Material Figure B]. A resuscitation trolley was placed near the introitus for vaginal delivery and next to the Operation Theatre table for lower uterine segment caesarean section, keeping in mind that we did not interfere with the obstetric care of the mother and without stretching the umbilical cord. This trolley was designed to have easy manoeuvring, lightweight, easily movable, adjustable bassinet

height, rotatory basinet in any direction up to 360 degrees, and capable of providing warmth by phase contrast materials. Resuscitation, including PPV, was feasible on this trolley if required. Resuscitation was conducted while keeping the cord intact till the placental was separated. Initial steps, including drying, stimulation, and suctioning if required, were completed within 45 sec. All the essential parameters, including HR, ECG $Sp0_2$, and pulse, were recorded continuously during resuscitation.

If the baby did not require any resuscitation, the baby was put on the mother's chest to continue skin-to-skin contact, while encouraging the baby to take the breastfeeding. Management of newborns was based on HR ascertained by dry ECG-based electrodes.

Ethical Considerations: The study was performed following the Declaration of Helsinki. The work has been approved by the ethical committees related to the institution in which it was performed. After giving information to parents about the purpose of the study, parents provided written informed consent for participation. This descriptive study was part of the research consortium improving newborn care, including a randomized controlled trial titled: "Intact cord resuscitation using HR as a primary driver versus standard resuscitation among vaginally born term and late preterm infants requiring resuscitation - A randomized control trial."

## Definitions

The first reliable HR was defined as the following:

1. For pulse oximetry: First HR obtained after reliable waveform tracing on pulse oximetry
2. For conventional ECG: First HR obtained after proper QRS complexes seen on ECG
3. For dry electrode ECG: First clear digital HR with the proper signal on the NeoBeat device as advised by the manufacture.

## Results

At the end of the study, 329 patients were enrolled in this study after getting parents' consent [Figure 1]. Out of 329 newborns, 305 had their first reliable HR >100 bpm, while 24 newborns had less than 100 bpm [Table 1]. Within these 24 newborns (initial HR <100/min), 14 (58%) initiated respiration with initial steps, and the rest, 10 (42%), required resuscitation in the form of PPV. Among newborns with a first HR of more than 100 bpm, 297 had spontaneous respiration within 30 sec of life and the rest 8 newborns required resuscitation after initial steps failed to initiate breathing [Table 2].

The median duration to capture the first reliable HR among the cohort was 15 sec (IQR 12.7–20 sec) using a dry ECG-based electrode, which was much faster than the time required by conventional ECG (median 37, IQR 33–49) and pulse oximetry (median 80, IQR 51–120) [Figure 2].

The proportion of neonates requiring PPV at 1 min was significantly higher in the group having an initial first reliable HR of less than 100 as compared to a first reliable HR of more than 100 (41.6% vs. 2.6%).

Considering ECG to be more reliable and the gold standard, pulse oximetry tends to underestimate HR till 10 min, more so till 3 min of life [Supplementary Material Figure C].

On analysis of the HR trend during the initial 120 sec among all 329 neonates, it was observed that newborns with the first reliable HR of less than 100 bpm, which failed to increase at 30 sec despite initial stimulation, persisted in having low HR at 75 sec of life, despite adequate PPV commencement according to NRP guideline [Figure 3]. However, the requirement of labour room CPAP (45%) and incidence of intubation (12.5%) were higher among these groups compared to neonates with an initial HR of more than 100 bpm.

Further, neonates with an initial first HR above 100 but having a rapid falling HR at 45 sec of life despite initial steps also had persisted low HR at 75 sec despite starting PPV according to NRP 2020 guidelines.

**Table 1: Comparing demographic detail neonates with first reliable heart rate less than 100 versus more than 100 beats per minute**

| | First reliable heart rate <100 (*n*=24) | First reliable heart rate >100 (*n*=305) |
|---|---|---|
| Mother's age (Median) | 27 yrs. | 27 yrs. |
| Range | 23-31 yrs. | 19-43 yrs.' |
| Birth weight (in grams) Median (IQR) | 2219 gm (2029-2416) | 2870 gm (2650-3050) |
| Gestation | | |
| Term | 19 (80%) | 265 (87%) |
| Late preterm | 3 (12.5%) | 23 (7.5%) |
| Moderate term | 1 (4%) | 9 (3%) |
| Very preterm | 1 (4%) | 8 (2.6%) |
| Mode of delivery | | |
| Vaginal | 11 (45%) | 195 (64%) |
| LSCS | 13 (55%) | 109 (35.7%) |
| Instrument | 0 | 1 (0.3%) |
| Gender | | |
| Male | 11 (47%) | 158 (52%) |
| Female | 13 (53%) | 147 (48%) |
| Antenatal risk factor | | |
| GDM | 1 (4%) | 45 (15%) |
| PIH | 4 (16%) | 26 (8.6%) |
| Fetal distress | 0 | 10 (3.3%) |
| Therapeutic hypothermia | 0 | 0.3% (*n*=1) |
| CPAP requirement | 11 (45%) | 52 (17%) |

**Table 2: Distribution of first heart rate and the percentage of resuscitation required among all neonates (*n*=329)**

| 1st reliable Heart rate | <100/min | >100/min |
|---|---|---|
| No. of neonate (*n*) | 24 | 305 |
| Resuscitation required | 10 (41%) | 8 (2.2%) |
| Resuscitation not required | 14 (595) | 297 (97.8%) |

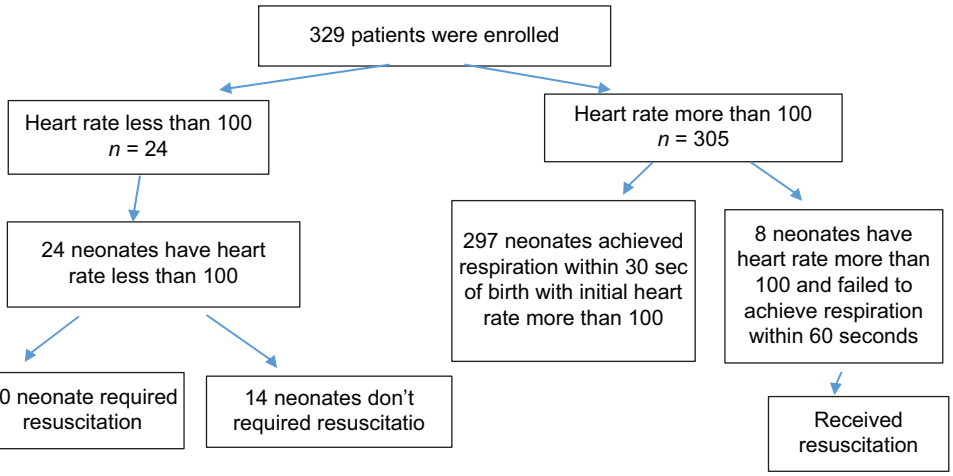


**Figure 1:** Flow chart showing the participation of patients and primary division based on initial first reliable heart rate

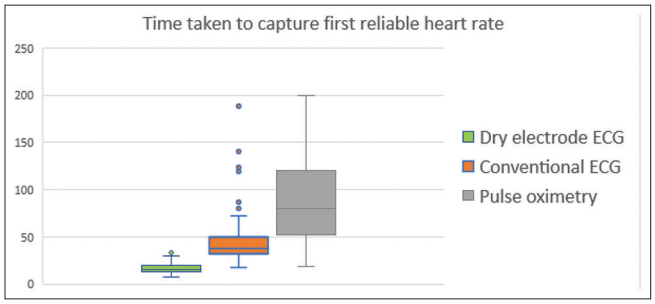


**Figure 2:** Comparison of time to first reliable heart rate detection between pulse oximetry, dry electrode based ECG and conventional ECG

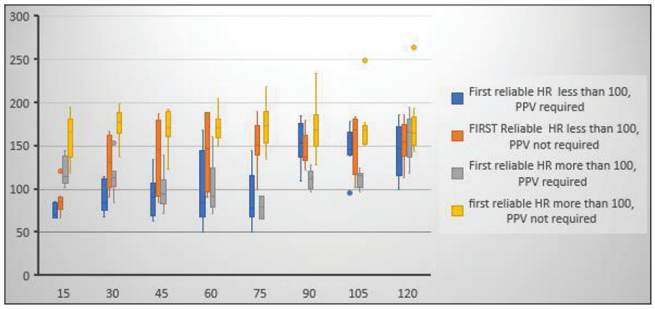


**Figure 3:** Comparison of first reliable heart rate among various subgroup and its trend over initial 120 seconds among neonates based on their first reliable heart rate and requirement of PPV

## Discussion

This study re-emphasizes the importance of HR as a marker of extra-uterine transition following birth. Obtaining an HR within 60 sec of life may improve the survival of neonates and guide further intervention.[8] However, underestimating HR can result in unnecessary resuscitation practice, and overestimating HR can potentially delay life-saving resuscitation.[16] Previous studies have already proven that ineffective HR assessment can increase the chance of hypoxic brain injury in neonates. In addition, initial HR assessment can help to predict the mortality and morbidity (grade of brain injury) in resuscitated neonates.[17] Therefore, finding a fast, reliable, and accurate method of estimating HR is crucial in guiding resuscitation actions.

In this study, we observed that HR predicts the increased requirement for resuscitation or labour room CPAP. The resuscitation requirement was very high (41%) in a group with 1st reliable HR of less than 100 compared to (2.2%) in a group with HR of more than 100 bpm. Thus, achieving 1st reliable HR within 30 secs can help us to better anticipate the requirement of resuscitation in the next 30 secs of life.

### Importance of HR trends in deciding resuscitation and current NRP recommendation?

Current NRP guidelines suggest initiation of PPV if HR <100 bpm or the neonate fails to achieve spontaneous breathing within 1 min of life. In addition, If HR drops below 60 bpm, chest compression is advised. However, these cutoff values do not have any rigorous scientific evidence.

A recent nomogram based on a technique using ECG showed that show that in spontaneously breathing infants, HR increases initially from 120 to 170 bpm during the first 5 to 30 sec after birth, maximizing at 1 min to 175 bpm before slowly decreasing at 5 min.[18] These are in contrast to the nomogram obtained using pulse oximetry, which shows lower HRs. HR increment in preterm infants is slower as compared to a term infant.[19] Our study also shows similar HR nomograms.

Surprisingly, recent data from various studies have shown that about half of neonates in compromised states requiring PPV may have the first detectable HR of more than 100 bpm.[20,21] However, the number of these studies remain limited to formulate any solid guidelines, and more work still needs to be done. These studies may provide an insight that initial single HR alone may be insufficient to guide any resuscitation, and continuous feedback monitoring may play an important role in deciding initiation resuscitation and monitoring of resuscitation.

Similarly, a small proportion of our cohort (2.2%) have a first reliable median HR of more than 100 bpm (114, IQR-107–138) and need PPV to initiate respiration. These group neonates had falling HR at 30 sec and showed an HR drop below 100 bpm at

45 sec and needed a prolonged time (90 sec) to recover HR above 100 bpm (median 111, IQR-120–100 at 90 sec). The prolonged recovery time may be explained by the delayed starting of PPV based on the first reliable HR above 100 bpm. Thus, monitoring falling HR trends at 30 sec may have important predictive impacts on such resuscitation and can improve neonate resuscitative care.

In our cohort, analysis of data of neonates who failed to achieve spontaneous breathing till 30 sec of life emphasized the importance of the HR trend. All neonates with decreasing HR trends within 30 sec of birth required resuscitation, and neonates who did not require resuscitation showed increasing HR trends. Thus, the decision to continue the initial steps or proceed to PPV can be effectively made at 30 sec by monitoring the first HR and its trends.

These further show us that PPV can be used judiciously in the labour room without causing any harm by delaying resuscitation. In addition, resuscitation can be solely guided by HR and its trend till placental circulation occurs and give time to the baby to establish breathing with initial steps or on its own.

Our finding was supported by previous studies, where Pulse oximetry-derived HR was significantly lower than ECG-based HR.[22] Critical intervention and steps at the time of resuscitation, such as correcting ventilator steps or timely intubation/chest compression, can be delayed if HR is presented inaccurately or there is a delay in measuring HR at birth. However, underestimating HR can lead to unnecessary intervention at the time of birth.

### Why is timely initiation of resuscitation so important and HR and its predictive value on the outcome?

Initial HR and its response to PPV have an important predictive value on neonatal resuscitation. In low-resource settings, there is a 75% reduction in risk of mortality in neonates that demonstrates an initial fast increase in HR to more than 100 in response to resuscitation (PPV). However, a 2-fold increase in mortality is seen in neonates having decreased HR below 100 bpm during a pause in resuscitation. Obtaining HR within 60 sec of life may improve the survival of neonates and guide further intervention. Moreover, underestimating HR can result in unnecessary resuscitation practice, and overestimating HR can potentially delay life-saving resuscitation.

### Practical difficulties while using conventional ECG

It was very difficult to apply conventional ECG electrodes just after birth. Skin was usually wet after delivery and ECG electrodes were misplaced frequently. Neonates were vigorous during the initial period, and these body movements were associated with frequent displacement of electrodes.

The limitations of this study are the short sample size and the observational nature of the study. A well-formulated randomized controlled trial can provide a better outlook on this view and further strengthen the hypothesis that early HR monitoring can improve the rational use of neonatal resuscitation in neonates with intact cord resuscitation.

Implication for physicians at a basic level: Perinatal asphyxia is one of the most important reasons for neonatal mortality and neurodevelopmental morbidity in our country. HR is the most important factor in starting and monitoring the efficacy of resuscitation. Early and reliable HR detection will guide the treating primary care physician in reviving a neonate after birth. Dry electrode devices are the fastest in the detection of reliable HR after birth as compared to conventional methods. It is also feasible to apply neonates just after birth, and data can be recorded and saved electronically.

## Conclusion

First reliable HR can effectively predict the need for neonatal resuscitation. Dry electrode ECG can effectively capture continuous and reliable HR during the initial 30 sec of life. HR trends can further assist in predicting the need for neonatal resuscitation and the efficacy of neonatal resuscitation. Pulse oximetry tends to underestimate HR in the initial minutes of life and can lead to inappropriate PPV or chest compression. Further multi-centric randomized control trials are needed to generate robust evidence before any recommendation can be given.

### List of abbreviations

| Abbreviations | Definition |
|---|---|
| AAP | American Academy of Pediatrics |
| DCC | Delayed Cord Clamping |
| ECG | Electrocardiogram |
| HR | Heart Rate |
| ILCOR | International Liaison Committee on Resuscitation |
| NRP | Neonatal Resuscitation Program |
| OT | Operation Theatre |
| PPV | Positive Pressure Ventilation |

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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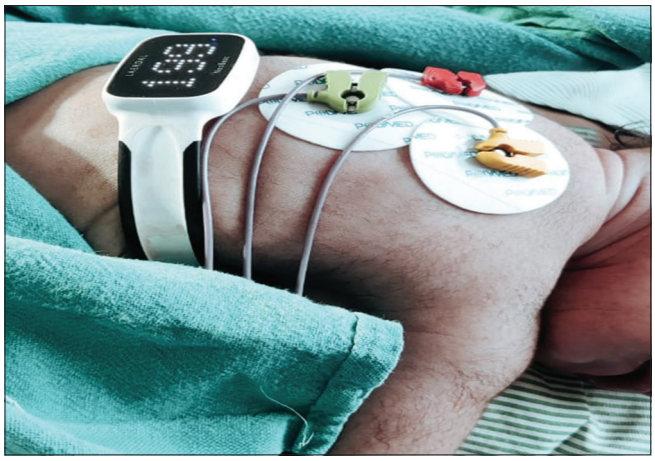
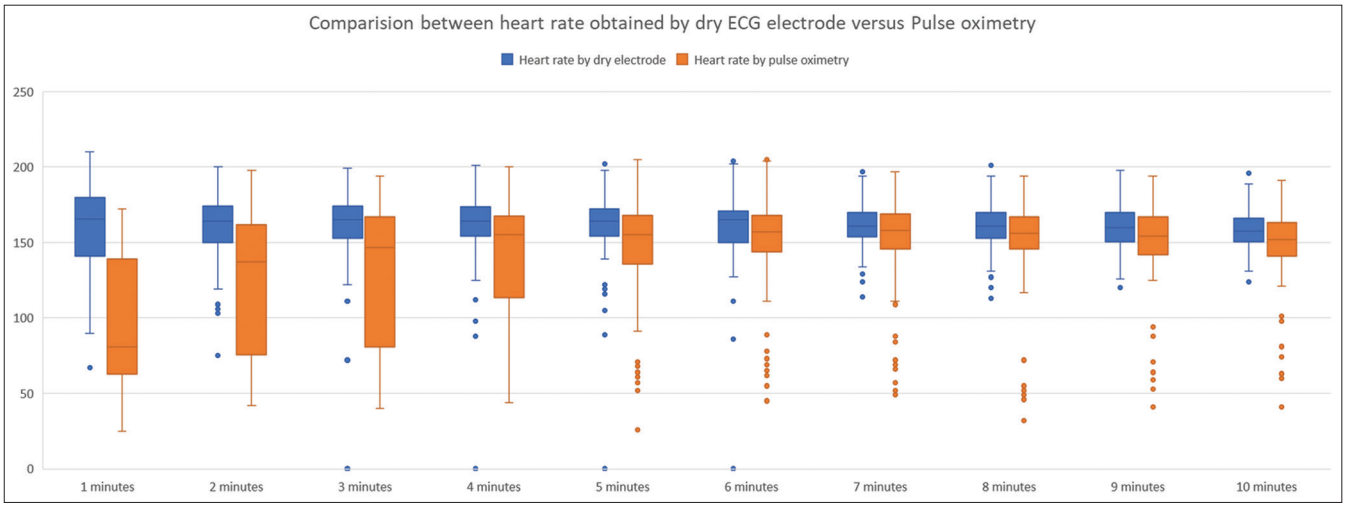


**Supplementary Material Figure A:** Newborn placed on mother's chest with Neobeat and conventional modified 3 electrodes (pre-formed 3-lead ECG) applied on back

**Supplementary Material Figure B:** Modified resuscitation trolley for purpose of intact cord resuscitation




**Supplementary Material Figure C:** Comparing Heart rate captured by pulse oximetry and ECG after 1 minutes till 10 minutes