Electrocardiogram Provides a Continuous Heart Rate Faster Than Oximetry During Neonatal Resuscitation

**WHAT'S KNOWN ON THIS SUBJECT:** Heart rate continues to be the single most important indicator of well-being in a newborn. Availability of a reliable method to determine heart rate in the first minute would help determine resuscitation interventions, particularly for the extremely premature infant.

**WHAT THIS STUDY ADDS:** Electrocardiograms can provide a reliable, continuous heart rate in the most premature infants in the first minute of resuscitation compared with pulse oximeters.

**abstract**

**OBJECTIVE:** To compare the time required to obtain a continuous audible heart rate signal from an electrocardiogram (ECG) monitor and pulse oximeter (PO) in infants requiring resuscitation.

**METHODS:** Infants who had both ECG and PO placed during resuscitation were analyzed using video and analog recordings. The median times from arrival until the ECG electrodes and PO sensor were placed, and the time to achieve audible tones from the devices, were compared.

**RESULTS:** Forty-six infants had ECG and PO data. Thirty infants were very low birth weight (23–30 weeks). There was a difference in the median total time to place either device (26 vs 38 seconds; \( P = .04 \)), and a difference \( (P < .001) \) in the time to achieve an audible heart rate signal after ECG lead (2 seconds) versus PO probe (24 seconds) placement. In infants weighing \( >1500 \) g \((n = 16)\), the median time (interquartile range) to place the ECG was 20 seconds (14–43) whereas the time to place the PO was 36 seconds (28–56) \( (P = .74) \). The median times (interquartile range) to acquire a signal from the ECG and PO were 4 seconds (1–6) and 32 seconds (15–40, \( P = .001 \)), respectively. During the first minutes of resuscitation, 93% of infants had an ECG heart rate compared with only 56% for PO.

**CONCLUSIONS:** Early application of ECG electrodes during infant resuscitation can provide the resuscitation team with a continuous audible heart rate, and its use may improve the timeliness of appropriate critical interventions. *Pediatrics* 2012;130:e1177–e1181
Heart rate is the most important objective indicator of the status of an infant immediately after birth. According to the current American Academy of Pediatrics Neonatal Resuscitation Program guidelines, the primary measure of adequate initial ventilation is an increase in heart rate. At the UCSD Medical Center NICU, our practice had been to obtain an immediate continuous heart rate using auscultation or cord palpation, and provide this information to the resuscitation team by a tapping finger movement until the pulse oximeter (PO) provided a continuous reliable heart rate. Previous editions of the Neonatal Resuscitation Program guidelines stated that heart rate should be reassessed every 30 seconds after birth. The current edition suggests that if an individual hears a heart rate that he or she “tap it out on the bed so that others will also know the heart rate,” implying that a continuous heart rate assessment is preferred. The use of a PO or electrocardiogram (ECG) electrodes are recommended only if the individual cannot assess the heart rate.

This approach requires the full attention of a team member who must detect the correct pulse rate, calculate the heart rate, and communicate either the timing of the pulse or the calculated heart rate to the team. This requires that the individual remain in direct physical contact with the infant, leaving that member unavailable for other resuscitation tasks. In very low birth weight (VLBW) infants, auscultation of the heart rate can be challenging, leading to delayed or incorrect interventions. Moreover, auscultation or palpation of the umbilical cord have been shown to be inaccurate, systematically underestimating the heart rate by an average of 14 and 21 beats per minute, respectively.

Our experience and evidence from other studies show that a PO-derived heart rate is not usually available within the first minute of life. As a result, we have begun to place ECG electrodes immediately after delivery to provide an earlier continuous heart rate to the resuscitation team. Current data comparing ECG with PO are conflicting as to which device can produce a reliable heart rate faster. To our knowledge, no study to date has determined whether an ECG can produce an early reliable continuous heart rate in infants <1500 g. We hypothesized that an ECG would provide a reliable heart rate more rapidly than a PO in VLBW infants during the first minutes after birth.

METHODS

Data Collection

To improve the quality and effectiveness of our neonatal resuscitations, we developed a real-time data acquisition system, which includes video and audio recordings as well as analog data for all monitored parameters. The infant's pulse rate and oxygen saturation were collected from the PO (Radical-7, Masimo Corporation, Irvine, CA). ECG readings were obtained from the defibrillator output of the heart rate monitor (M3046A, Phillips Medical Systems, Andover, MA), along with other physiologic signals not part of this study. Data were converted from analog to digital using a universal interface module attached to an MP150 data acquisition system (Biopac Systems, Inc, Goleta, CA). All channels were sampled at 200 samples per second (Hz), and the files were linked to the video to allow for review of temporal relationships. The camera was a Sony HDR-XR160 high-definition video camera (Sony Electronics, San Diego, CA) mounted to the resuscitation bed using a Manfrotto/Bogen Model 244 variable friction Magic Arm with camera bracket and model 035RL Super Clamp (Manfrotto Supports, Cassola, Italy).

Infant data were collected from the time the infant was placed on the warmer until either the infant was removed from the bed to be taken to the nursery or the face of the PO was removed. For purposes of this study, we analyzed the portion of these data from the time the infant was placed on the bed until both monitoring devices were providing audible indicators of heart rate. The time to place ECG leads was calculated from the time the infant was placed on the bed until the third ECG lead was placed. The time to place the PO was calculated from the time the infant was placed on the bed until the PO sensor was connected.

Lead/Electrode Placement

Before delivery, the electrographic lead wires (Red Dot, 3M, St Paul, MN) were removed from the packet by a neonatal nurse and connected to a heart rate monitor. When the infant was placed on the radiant warmer after delivery, the infant's chest was briefly dried, and 1 ECG lead was placed on the right side of the chest and 2 ECG leads were placed on the left side of the chest. Infants <29 weeks' gestation were placed in a polyethylene wrap immediately after drying. The plastic wrap was briefly pulled back to allow for chest lead placement. An oxygen saturation sensor (LNOP Newborn, Masimo Corporation, Irvine, CA) was wrapped on a preductal site, usually the right wrist, at approximately the time before plugging this sensor into the PO (per the manufacturer's recommendation) by a respiratory therapist. The timing of placement of both devices was not simultaneous and was dependent on the providers. A stethoscope was used to listen to the heart rate until 1 of the devices was functioning. There was a minimum of 3 providers (a nurse, a respiratory therapist, and a physician or neonatal nurse practitioner) at every high-risk delivery.

Validation

Both the PO and the ECG heart rate monitor have sophisticated algorithms...
for qualifying signal integrity. They are designed to begin providing an audible pulse/heartbeat signal when the device has recognized a signal of adequate quality. A sample ECG showing time of placement and time of audible signal is shown in Figure 1. The audible signal occurs after either the ECG monitor detects recognizable QRS complexes or plethysmographic waveforms are recognized by the PO. For this reason, we used the time from placement of the infant on the bed to detection of an audible heartbeat as the indicator in both devices that a usable signal had been obtained. Both devices produce a distinct audible heartbeat that can be heard clearly during the resuscitation. This is particularly appropriate because it is the signal used by the clinicians at the delivery to determine heart rate.

A single investigator (Mr Rich), who had not attended any of the resuscitations, reviewed the video recordings and recorded the time of placement for each device (ECG or PO). To determine the time to acquire a reliable signal, the time from placement of either device until the device provided an audible heartbeat was recorded. The types of resuscitation interventions and patient demographic characteristics (gestational age and birth weight) were also recorded.

**Statistical Analysis**

The medians and interquartile ranges (IQRs) of times for ECG and PO to be placed and acquire reliable signals were compared by using Wilcoxon signed rank test (SPSS Inc, Chicago, IL). The institutional review board of UCSD approved a waiver of consent for the study.

**RESULTS**

During July 2011–February 2012, all 46 video resuscitation recordings that included both ECG and PO data were reviewed. Thirty infants born during this time period were VLBW, with a mean birth weight of 931 ± 291 g and a mean gestational age of 27 ± 2 weeks. Of these 30 infants, resuscitation required was as follows: none \((n = 2)\), mask continuous positive pressure ventilation \((n = 27)\), endotracheal positive pressure ventilation \((n = 7)\), and chest compressions \((n = 2)\). The median time (IQR) to place the ECG was 26 seconds \((17–41)\) whereas the time to place the PO was 38 seconds \((33–44)\) \((P = .04)\). The median time (IQR) to acquire a reliable heart rate value with the ECG was 2 seconds \((1–4)\) whereas the median time to acquire a stable heart rate from the PO was 24 seconds \((16–35)\) \((P < .001)\).

The devices were placed at the same time in 1 infant, and 7 infants had their ECG placed after the PO was placed. Two of these infants had a longer total time to acquire a heart rate with the ECG compared with the PO. An analog tracing of the ECG and the PO in 1 infant is shown in Fig 2. During the first
minute of resuscitation, 27 of 30 infants had a functioning ECG compared with 12 of 30 infants with a functioning PO pulse rate. There was no significant difference in the time to place ECG or PO or admission temperature differences in infants who were wrapped in plastic (<29 weeks) compared with those who were not (data not shown).

A separate analysis of timing of ECG and PO placement for infants weighing >1500 (mean birth weight: 2435 ± 823 g; gestational age: 35 ± 3 weeks) was also performed. The median time (IQR) to place the ECG was 20 seconds (14–43), and the time to place the PO was 36 seconds (28–56) (P = .74). The median times (IQR) to acquire a signal from the ECG and PO were 4 seconds (1–6) and 32 seconds (15–40) (P = .001), respectively. During the first minute of resuscitation, all infants weighing >1500 g had a functioning ECG compared with 8 of 16 infants with a functioning PO pulse rate.

**DISCUSSION**

This is the largest study to evaluate the ability to obtain a continuous heart rate with ECG compared with PO in VLBW infants. Significantly more infants had an audible heart rate within the first minute by ECG than by PO. For neonates requiring resuscitation, early information about heart rate may help with determining the effectiveness of mask positive pressure ventilation or whether interventions such as intubation are required. Similarly, an improving heart rate may also indicate that no intervention is needed and that intervening with mask pressure may be deleterious, resulting in an inadvertent vagal reflex.

Our center has had trained respiratory therapists placing POs immediately after birth for the past 12 years. However, we have not had consistent success in obtaining continuous heart rates with POs in the first minute of life. Recently, our neonatal nurses who attend high-risk deliveries were trained to place ECG leads immediately at the time of delivery. The ECG leads are placed on

![FIGURE 2](image)

Analog tracings of an infant’s continuous heart rate tracing with an ECG and a PO over time.
the chest wall, after rapid drying of the area, because limb leads were found to be cumbersome and less dependable. This strategy has proved to be very effective and has likely contributed to earlier placement of ECG leads. Placing chest leads has not affected the practice of immediately wrapping the infants in a polythene wrap because this practice was performed immediately after birth while the chest is briefly exposed during ECG and PO placement. Because this study was performed as part of a quality improvement project, we did not have a formalized protocol for how quickly ECG leads should be placed. Therefore, some of the infants had ECG leads placed as late as 95 seconds of life. Nonetheless, we found no significant difference in the time to place ECG leads versus the PO probe. We believe that with a formalized protocol, the time to place ECG leads can be even shorter.

Two studies have directly compared ECG with PO in achieving a continuous reliable heart rate during neonatal resuscitation. Our results contradict the previous report by Kamlin et al, which describes the use of ECG and PO in 55 deliveries. They reported that the median time to acquire a reliable heart rate by PO was earlier than the median time to acquire a heart rate by ECG (68 vs 80 seconds). In contrast, a recent paper by Mizumoto et al demonstrated that ECG acquired a heart rate much earlier than PO (median: 38 vs 122 seconds after delivery) in 20 infants. Both studies had only a few VLBW infants, with an average birth weight of 2399 and 2388 g, respectively. By comparison, our study included the highest-risk population of infants weighing <1500 g. The delay in achieving a heart rate signal by ECG in the study by Kamlin et al may have been due to a delay in lead placement, although it is not known if there was a delay in placement of the ECG leads compared with PO. In the current study, we addressed both the time of placement of each device and the time to achieve a reliable signal. We used chest leads for placement because they can be placed quickly without delay. We did not encounter any problems with lead adhesion with thick vernix, as suggested in the study by Mizumoto et al, likely because the infants were premature. Conversely, there were no reports of skin damage from lead placement in our group despite inclusion of infants as immature as 23 weeks’ gestation.

CONCLUSIONS

Our study found that ECG provided a continuous reliable heart rate during the first minute of life, well before a PO produced a reliable heart rate signal. The use of ECG during resuscitation will free up a member of the team to perform other tasks. Additional studies are needed to demonstrate whether early information regarding heart rate can improve the need for more (or less) resuscitation and whether this leads to improved postnatal outcomes.

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*Pediatrics* 2012;130;e1177; originally published online October 22, 2012; DOI: 10.1542/peds.2012-0784
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