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Electronic Heart (ECG) Monitoring at Birth and Newborn Resuscitation

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Abstract: Neonatal electronic cardiac monitoring in labor and delivery room (DR-ECG) is shown to be sustained at a tertiary care regional perinatal center despite COVID-19 and other complex organizational challenges. In this contemporary cohort, initial increase in chest compressions at birth associated with the introduction of DR-ECG monitoring was mitigated by focused educational interventions on effective ventilation with no difference in neonatal mortality. DR-ECG may help our understanding of human and system factors, identify potential better practices for optimal resuscitation team performance and assess impact of targeted training initiatives on clinical outcomes.

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1. Introduction

Neonatal heart rate is an important measure used in the delivery room (DR) to guide the progression and success of resuscitative interventions. In 2016, the American Heart Association updated its guidelines to suggest the use of electrocardiographic (ECG) leads for accurate neonatal heart rate monitoring in infants receiving resuscitation [1].

Previous studies have shown that ECG provides a faster and more accurate measure of heart rate compared to pulse oximetry or auscultation, especially in the first minutes [2]. Earlier measures of heart rate should allow for earlier intervention initiation. However, the impact of ECG use in the delivery room on clinical outcomes is still being investigated [3].

Our level IV NICU at Oklahoma Children's Hospital integrated routine use of 3-lead ECG in the DR for neonates receiving positive pressure ventilation (PPV) or higher support in 2017. We previously evaluated patterns of DR interventions between pre-implementation (2015) and post-implementation (2017) cohorts of ECG use in the DR [4].

The objectives of this study were to evaluate serial trends in frequency of DR interventions including among a recent cohort of infants born in 2021, compare their results with those of infants born in 2015 and 2017, and any differences in the cohorts' neonatal outcomes.

2. Methods

This longitudinal cohort study analyzed maternal and infant data abstracted from medical records by trained staff at Oklahoma Children's Hospital at the University of Oklahoma Health Sciences Center. Participants included in-born infants admitted to our hospital who received PPV or higher support in the DR. This study included cohorts from 2015 (pre-implementation of ECG use), 2017 (upon implementation), and 2021 (4 years post-implementation).

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The cohorts were compared on maternal demographics, delivery room interventions, and neonatal outcomes. Delivery room variables included oxygen use, PPV, continuous positive airway pressure (CPAP), tracheal intubation, chest compressions, epinephrine use, and APGAR scores (1, 5 and 10 minutes after birth). We also investigated neonatal death during the hospital stay. Groups were compared using linear mixed models with the subjects nested in cohorts as a random factor. Binary outcomes were analyzed using a generalized multilevel model with a logistic link function, and a Gaussian link was used for continuous outcomes.

3. Results

Table 1 compares the cohorts on delivery room variables and interventions as well as in-hospital neonatal mortality. Positive pressure ventilation use at birth was significantly higher in the post-implementation cohorts (2017, 2021) compared to pre-implementation (2015). Cohort 2017's higher chest compressions compared to 2015 showed a trend toward significance (P<0.10), then the rate decreased significantly from 2017 to 2021, when the rate was statistically indistinguishable from 2015. Tracheal intubations decreased from 2015 to 2017, then increased in 2021, returning to a rate that was statistically equivalent rate to 2015 [4].

Table 1. Delivery room variables and in-hospital mortality.

Variable	**2015, N = 263 n (%) or median (IQR)**	**2017, N = 369 n (%) or median (IQR)**	**2021, N = 379 n (%) or median (IQR)**
Positive pressure ventilation	239 (91.9) $^{A, B}$	360 (97.6) ^{A}	365 (96.3) ^{B}
Tracheal intubation	125 (47.5) ^{A}	131 (35.5) $^{A, B}$	166 (43.8) ^{B}
Chest compressions	8 (3.0)	24 (6.5) ^{A}	8 (2.1) ^{A}
Epinephrine use	1 (0.4)	5 (1.4)	7 (1.9)
APGAR scores			
1 min	3 (2, 6)	4 (2, 6)	4 (2, 6)
5 min	6 (5, 8)	7 (5, 8)	7 (5, 8)
10 min	7 (7, 8)	7 (7, 8)	7 (7, 8)
Supplemental oxygen	224 (85.2) ^{A}	330 (89.4) ^{B}	378 (99.7) $^{A, B}$
Continuous positive airway pressure	186 (70.7) $^{A, B}$	323 (87.5) ^{A}	329 (86.8) ^{B}
In-hospital mortality	23 (8.7)	30 (8.1)	32 (8.4)

Columns that share the same superscript on a row differed significantly, p < .05. IQR = interquartile range.

Analyses of other maternal and perinatal characteristics and other neonatal outcomes are available for review in the supplemental material (see Appendix A).

4. Discussion

Contemporaneous heart rate evaluation by ECG at birth showed no significant changes in mortality compared to auscultation or palpation. However, cohort 2021 had a significantly higher percentage of tracheal intubations and lower percentage of infants receiving chest compressions in the DR when compared to cohort 2017.

Multiple factors could explain significant differences between the frequency of DR chest compression and tracheal intubation between 2017 and 2021. In 2019, an interdisciplinary project targeting neonatal resuscitation program (NRP®) providers and instructors on the timely implementation of establishing early rescue airway to effectively deliver positive pressure ventilation during troubled transitions at birth was carried out [5].

These focused educational interventions on ventilation, including laryngeal mask, along with incorporation of dedicated transition nurses in labor and delivery rooms may have mitigated the previously increased, though statistically not significant, frequency of chest compressions. In addition, the impact of COVID-19 pandemic on human factors, including further strain on already

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limited staffing and finite system resources as well as variable levels of training, awareness and experience among frontline providers could have contributed to these differences.

5. Conclusions

We demonstrate ECG implementation in the DR can be sustained at a large, academic level IV NICU despite COVID-19 and other organizational challenges. Accurate and reliable early heart rate detection by DR-ECG may help identify potential best practices and evaluate impact of targeted training initiatives on resuscitation team performance. Therefore, further incorporation of electronic heart monitoring during neonatal resuscitation needs systematic evaluation in order to investigate the impact on clinical outcomes as well as human factors and hospital resources.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of University of Oklahoma Health Sciences Center (IRB #14901).

Informed Consent Statement: Patient consent was waived due to study being a retrospective chart review.

Data Availability Statement: The de-identified data presented in this study are available on request from the corresponding author. The data are not publicly available due to compliance with HIPAA.

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Conflicts of Interest: The authors declare no conflict of interest. We are proud that this work was selected for abstract at the 2022 *Society of Pediatric Research* annual meeting.

Appendix A

Generalized linear models and a logistic linking function were run for all of the outcomes in Table 1, with the exception of Apgar scores, for which a Gaussian linking function was used. Unlike the multivariable analyses reported in Shah et al. [4], this paper omitted the covariates of race and use of forceps or vacuum because of sparse cells making the analysis untenable. Otherwise, the same covariates were included in the models:

- Documented use of tobacco, alcohol, or illicit drugs
- Pre-eclampsia
- Diabetes mellitus
- Antenatal antibiotics
- Intrauterine growth restriction
- Steroids
- Magnesium
- Meconium
- Any cord accident
- Abnormal hearth pattern
- Antepartum hemorrhage
- General anesthesia

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- Urgent Cesarean delivery
- Gestational age (weeks)

Table A1 shows the pattern of results for each outcome from the unadjusted analyses reported in Table 1 and the pattern of results from the adjusted (multivariable) analyses; an equal sign means the rates for that outcome did not differ significantly between the years shown, while directional sign indicates a significant difference in the direction shown. Rows have been added under each outcome to list the significant covariates (P < 0.05). The last column shows those covariates' odds ratios or, in the case of APGAR scores, regression coefficients, as well as their associated 95% confidence intervals.

Table A1. Multivariable Analysis of Delivery Room Variables and Neonatal Mortality.

Outcome Variable	Unadjusted Comparison of Years	Adjusted Comparison of Years	Odds Ratios (95% CI) or Regression Coefficient (95% CI)
Positive pressure ventilation	2015 < 2017 = 2021	2015 < 2017 = 2021	
Steroids			3.63 (1.46, 9.43)
Cord accident			0.24 (0.07, 0.98)
Gestational age			1.11 (1.02, 1.22)
Tracheal intubation	2017 < 2015 = 2021	2015 = 2021 2017 = 2021 2015 > 2017	
Steroids			0.41 (0.26, 0.65)
Meconium			1.97 (1.12, 3.49)
General anesthesia			2.01 (1.33, 3.03)
Urgent Cesarean			1.56 (1.03, 2.35)
Gestational age			0.81 (0.77, 0.85)
Chest compressions	2015 = 2021 > 2017	2015 = 2021 > 2017	
Abn. heart pattern			3.37 (1.48, 7.77)
General anesthesia			3.29 (1.45, 7.52)
Gestational age			0.86 (0.78, 0.95)
Epinephrine use [a]	2015 = 2017 = 2021	2015 = 2017 = 2021	
APGAR score, 1 min	2015 = 2017 = 2021	2015 = 2017 = 2021	
Steroids			1.04 (0.59, 1.49)
Meconium			-0.69 (-1.29, -0.10)
Abn. heart pattern			-0.73 (-1.14, -0.32)
General anesthesia			-1.06 (-1.47, -0.64)
Gestational age			0.12 (0.08, 0.17)
APGAR score, 5 min	2015 = 2017 = 2021	2015 = 2017 = 2021	
Steroids			0.69 (0.30, 1.07)
Cord accident			0.74 (0.01, 1.48)
General anesthesia			-0.83 (-1.18, -0.47)
Gestational age			0.13 (0.08, 0.17)
APGAR score, 10 min	2015 = 2017 = 2021	2015 = 2017 = 2021	
Pre-eclampsia			0.41 (0.01, 0.80)
Steroids			0.47 (0.06, 0.88)
Meconium			-0.56 (-1.08, -0.04)
Gestational age			0.09 (0.05, 0.14)
Supplemental oxygen	2021 > 2015 = 2017	2021 > 2017 > 2015	
Cord accident			0.28 (0.09, 0.95)
Continuous positive airway pressure	2015 < 2017 = 2021	2015 < 2017 = 2021	
Antibiotics			0.57 (0.35, 0.93)

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Steroids			3.59 (2.03, 6.49)
General anesthesia			0.60 (0.38, 0.98)
Gestational age			1.16 (1.10, 1.23)
Survival [c]			
Pre-eclampsia			2.83 (1.34, 6.33)
IUGR [b]	2015 = 2017 = 2021	2015 = 2017 = 2021	0.27 (0.14, 0.54)
Steroids			2.41 (1.17, 5.05)
Gestational age			1.20 (1.11, 1.30)

[a] No significant covariates, all P > .05. [b] IUGR = Intrauterine growth restriction. [c] This variable was reported as in-hospital neonatal mortality in Table 1 to be consistent with Shah et al. [4], but in fact it was coded as survival (1 = yes, 0 = no). For interpretation of odds ratios for the covariates, the variable needs to be reported as it was coded.

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