PEDIATRIC SCIENCES JOURNAL
The Official Journal of the Pediatric Department, Faculty of Medicine, Cairo University, Egypt

Original Article

Electric Cardiometry is not Predictive of Outcome in Full-term Newborns with Respiratory Distress: A Single Center Study

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Received: 30/5/2023; Accepted: 20/6/2023; Published online: 25/6/2023

Abstract:
Background: Prompt management of respiratory distress (RD) among neonates is lifesaving. Electric cardiometry (EC) is not suitable for diagnosis, but its value in monitoring changes in cardiac parameters over time is in need of verification.
Aim of the Work: To study EC hemodynamic parameters predictive ability of outcome in full-term newborns with RD.
Materials and Methods: using electric cardiometry (EC) hemodynamic parameters were studied among 30 full term neonates with RD within the first 10 minutes of life and 2 hours later compared to another 30 without RD. The studied parameters were heart rate variability (HRV), cardiac output (CO), cardiac index (CI), stroke volume (SV), stroke index (SI), thoracic fluid content (TFC), stroke volume variation (SVV), index of contractility (ICON), left ventricular (LV) pre-ejection period (PEP), ejection time (ET), and systemic vascular resistance (SVR).
Results: The mean ± SD gestational age of the studied group was 38.20 ± 1.19 weeks, weight was 3.03 ± 0.51 kilogram, females were 15 (50%), and males were 15 (50%) which was comparable to the control group (p=0.584), (p=0.284) and (p=0.436) respectively. The mean Apgar score was less among the RD group; at one minute it was 6 and at 5 minutes was 8 (p=0.0001) and (p=0.002). Initial HRV, CO, CI, SV, SI, TFC, SVV, ICON, LV, PEP, ET, and SVR were not different among both groups but there was a significant decrease in CI (p=0.033), HRV (p=0.030), SI (p = 0.017), and SV (p= 0.016) in the RD group after 2 hours. Those with RD, 20 (66.6%) improved and 10 (33.3%) were admitted to the neonatal intensive unit. Both groups with RD had comparable HRV, CI, CO, SV, SI, TFC, SVV, PEP, ICON, LVET, or SVR in initial and the 2 hour of life assessment (p= 0.860), (p= 0.071), (p= 0.932), (p= 0.260), (p= 0.548), (p= 0.338), (p= 0.744), (p= 0.488), (p= 0.392), (p= 0.983), (p= 0.066) respectively.
Conclusion: Hemodynamic parameters assessed by electric cardiometry of full term neonates within 10 minutes of birth was not different among those with RD and those without. Electric cardiometry at 2 hours of life of those with RD was not predictive of outcome.

Level of Evidence of Study: IIB (*1*).
Keywords: full term neonates; electric cardiometry; respiratory distress
Abbreviations: CI: cardiac index; CO: cardiac output; EC: electric cardiometry; ET: ejection time; HRV: heart rate variability; ICON: index of contractility; LV: left ventricle; LVET: left ventricular ejection time; PEP: pre-ejection period; RD: respiratory distress; SI: stroke index; SV: stroke volume; SVR: systemic vascular resistance; SVV: stroke volume variation; TFC: thoracic fluid content.

Introduction

Massive hemodynamic changes occur during the transition to extra-uterine life. With birth comes loss of low resistance placental circulation and a decrease in pulmonary vascular resistance that result in a decrease in both pre and after-load of the right side of the heart. Meanwhile, lung aeration causes fluid absorption in the lung with shift to the pulmonary

vasculature and lymphatics that contribute to the increase in circulating blood volume. Loss of low resistance placental circulation and increased pulmonary blood flow increase preload as well as after-load of the left side of the heart (*2*). Hemodynamic instability associated with neonatal respiratory distress (RD) is a detrimental factor of outcome (*3*, *4*).

The electrical cardiometry (EC) has been proposed as a non-invasive, safe, simple, readily available, user friendly, prompt and non-operator dependent real-time monitor for hemodynamic monitoring in children and infants (*5*). It relies on the theory that the thorax is a cylinder filled with blood and that there is an inverse relation between the volume of blood and its resistance (impedance) to an electric current therefore this technique delivers a high-frequency, low-magnitude, alternative current and relies on alterations in thoracic electrical bio-impedance during the cardiac cycle to measure various cardiac parameters that allows for real-time monitoring (*6*, *7*). EC technology estimates blood flow and measures cardiac output (CO), cardiac index (CI) (CO normalized for body surface area), stroke volume (SV), and stroke index (SI) (SV normalized for body surface area). It measures thoracic fluid content (TFC) as well as stroke volume variation (SVV) from beat to beat. It assesses contractility by measuring the index of contractility (ICON) (peak acceleration of blood flow in the aorta), left ventricular (LV) pre-ejection period, and ejection time (PEP and ET) (*8*).

EC validation and agreement with echocardiography among pediatric populations were reported to be not clinically accepted with a 42% mean percentage error. It is not proved yet to be interchangeable with echocardiography because of the wide range of mean percentage errors in previous studies (*9*) but its use for monitoring changes in cardiac parameters over time is still an area for debate (*10*).

Monitoring neonatal hemodynamics by simple non-invasive methods may improve the timely intervention and outcome of newborns who have respiratory distress in this critical period. The objective of this work was to study EC hemodynamic parameters predictive ability of outcome in full-term newborns with RD within 10 minutes of birth and within the first two hours of life.

Subjects and Methods

This prospective study was conducted at Neonatology Unit, Cairo University Obstetric Hospital, over four months period from April 2021 to July 2021. The study was approved by the research ethics committee of Cairo University (Ethical Approval: MS-216-2021). Informed consent was given by each neonate guardians.

Participants

The study included 60 full-term newborns (≥ 37 weeks), after the early transition period (typically during the first 10 minutes of life) and within the first hour of life, and consecutively allocated into a case group (RD group) who had respiratory rate ≥ 60 breath/min or working accessory muscle of respiration or grunting or cyanosis and a control group (healthy babies with no signs of RD). Neonates with major congenital anomalies, those who were suspected to have congenital heart disease or congenital lung anomalies by antenatal ultrasound, or those who were older than one hour were not included in the study.

Methods

All studied full term neonates where examined carefully with special attention to Apgar score assessment respiratory distress grading using Downes' score (the clinical score to assess the severity of respiratory distress) (*11*, *12*), birth weight, blood pressure, and heart rate measurement.

They underwent EC using ICON (Osypka Medical, 1817405, Berlin, Germany): within the earliest 10 minutes of life, and at 2 hours of life for those with RD. It was applied using four standard surface electrocardiogram electrodes over the forehead, left lower neck, left mid-axillary line at the level of the xiphoid process, and lateral aspect of the left thigh. All measurements were performed on supine, quiet neonates. EC was set to record 6 measurements. Each at a 1-minute interval to take the mean value of readings. This was measured between 1 to 10 minutes after birth and repeated only in the case group two hours later. ICON is a small portable device that displays the measured parameters on its small screen.

Statistical Analysis

The data analysis was done using the Statistical Package for Social Science version 20 (SPSS v20, Chicago, IL, USA) after transforming the data from Excel 2010 sheet (Microsoft, USA). Categorical variables were presented by number and percentage. Data were coded and entered using (SPSS v28) (IBM Corp., Armonk, NY, USA). Data were summarized using mean, standard deviation, median, minimum, and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were done using the non-parametric Mann-Whitney test. For comparing categorical data, Chi-square (x^2) test was performed while the Fisher Exact test was used when the expected frequency is less than 5. P-values less than 0.05 were considered statistically significant.

Results

The study group included neonates who suffered from RD (n=30) and the second group included healthy newborns of the same age (n=30). There was no statistically significant difference between the two groups regarding gender (p= 0.436) and gestational age (p= 0.584). RD group had a statistically significant higher rate of CS delivery (p= 0.002) and statistically significant lower Apgar scores at 1 and 5 minutes (p= 0.000) and (p=0.002) respectively. (Table 1). Apgar scores at 1 and 5 minutes were not statistically different in those who improved and those who did not (p= 0.452 and 0.856 respectively). While those who improved had statistically lower Downes' scores (p< 0.001).

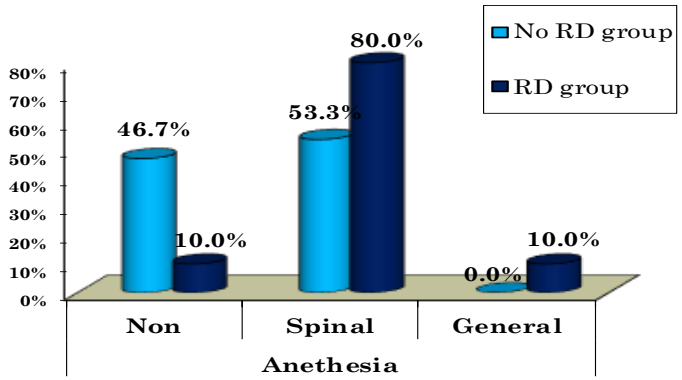

Figure 1. Maternal anesthesia modality during birth of studied groups.

Table 1. Comparison of characteristics of studied groups.

		Control group	RD group	P-value
		No. = 30	No. = 30	
Sex	Female	12 (40.0%)	15 (50.0%)	0.436
	Male	18 (60.0%)	15 (50.0%)	
Gestational age (weeks)	Mean ± SD	38.37 ± 1.16	38.20 ± 1.19	0.584
	Range	37 – 41	37 – 41	
Mode of delivery	NVD	14 (46.7%)	3 (10.0%)	0.002*
	C.S.	16 (53.3%)	27 (90.0%)	
Apgar score	Median	1 minute: 7	1 minute: 6	0.000*
		5 minutes: 9	5 minutes: 8	0.002*
Downes' score	Mean		5.6±1.19	--
	Range		4-8	
Weight (kg)	Mean ± SD	3.16 ± 0.33	3.03 ± 0.51	0.248
	Range	2.05 – 3.9	1.8 – 4.3	
HR (beat per minute)	Mean ± SD	142.97 ± 12.75	145.67 ± 11.26	0.388
	Range	115 – 159	117 – 164	
SBP (mmHg)	Mean ± SD	78.33 ± 4.53	77.87 ± 6.06	0.737
	Range	66 – 87	66 – 88	
DBP (mmHg)	Mean ± SD	44.70 ± 5.05	43.80 ± 6.27	0.543
	Range	35 – 54	30 – 56	

*P-value <0.05: Significant. RD: respiratory distress, NVD: normal vaginal delivery, CS: cesarean section, HR: heart rate, SBP: systolic blood pressure, DBP: diastolic blood pressure.

A cut-off value of <6.5 showed 95% sensitivity and 60% specificity for predicting improvement. There was a statistically significant higher incidence of RD in babies born to mothers who received anesthesia (spinal/general) (p-value 0.003). (Figure 1).

Of the mothers 47 (78%) were healthy, and 13 (22%) had illness; 4 (6.7%) and 1 (1.7%) (had pre-eclampsia, diabetes mellitus, and rheumatic heart disease respectively. Four (6.7%) mothers had meconium-stained amniotic fluid while one mother had placenta previa and one (1.7%) mother had premature rupture of membranes with no statistically difference between the two groups regarding maternal illness (p= 0.527). By examination, there was no statistically difference between the two groups regarding birth weight (p= 0.248), heart rate (p= 0.388), and systolic or diastolic blood pressure (p= 0.737) and (p=0.543) respectively. (Table 1). Downes' scores ranged from 4 to 8 with a mean of 5.6±1.19 in the RD group.

The 10 minutes of life ICON assessed parameters were not different between the two groups. (Table 2). The second assessment of the neonates with RD two hours later revealed a statistically significant decrease in CI, SV, SI, and HRV compared to their first readings. (Table 3).

The outcome in the RD group was as follows: 20 (67%) neonates improved and 10 (33%) were admitted to the Neonatal Intensive Care Unit. Of them; 7 neonates had transient tachypnea of the newborn, 2 had respiratory distress syndrome and 1 had congenital pneumonia. When comparing those who were admitted (n=10) to those who improved within the first few hours (n=20), there were no significant differences in HRV, CI, CO, SV, SI, TFC, SVV, PEP, ICON, LVET, or SVR neither on the first assessment (p= 0.628), (p= 0.791), (p= 0.414), (p= 0.961), (p= 0.420), (p= 0.794), (p= 0.456), (p= 0.514), (p= 0.792), (p= 0.954), (p= 0.660) respectively, nor the second assessment (p= 0.860), (p= 0.071), (p= 0.932), (p= 0.260), (p= 0.548), (p= 0.338), (p= 0.744), (p= 0.488), (p= 0.392), (p= 0.983), (p= 0.066) respectively.

Table 2. Correlation between ICON parameters in both the RD group and control group.

ICON Parameters		Control group No. = 30	RD group No. = 30	P value
HRV	Median (IQR)	16.5 (8.7 - 28)	19 (9.1 - 35)	0.819
	Range	3.4 – 769	3.4 – 867	
Blood flow				
CI [ml/min]	Median (IQR)	0.33 (0.3 - 0.41)	0.31 (0.28 - 0.42)	0.599
	Range	0.2 – 1.8	0.19 – 4.6	
CO [ml/min]	Mean ± SD	0.98 ± 0.24	0.94 ± 0.33	0.655
	Range	0.33 – 1.53	0.26 – 1.72	
SV [ml]	Mean ± SD	6.31 ± 1.65	6.76 ± 2.27	0.382
	Range	2.4 – 9.6	2.69 – 13.4	
SI [ml/m2]	Mean ± SD	2.23 ± 0.63	2.20 ± 0.64	0.871
	Range	1.34 – 4.71	1 – 3.93	
Fluid status				
TFC	Mean ± SD	77.83 ± 21.60	83.63 ± 26.99	0.362
	Range	16 – 110	40 – 155	
SVV [%]	Mean ± SD	26.23 ± 7.37	24.08 ± 9.33	0.326
	Range	11 – 43	8.5 – 47	
Contractility				
PEP [ms]	Mean ± SD	88.80 ± 14.53	91.20 ± 19.71	0.593
	Range	54 – 110	43 – 152	
ICON	Mean ± SD	126.67 ± 44.27	118.12 ± 63.05	0.546
	Range	56.2 – 276.1	25.3 – 306.6	
LVET [ms]	Mean ± SD	157.23 ± 30.99	169.87 ± 36.83	0.156
	Range	95 – 215	124 – 310	
Vascular system				
SVR [dyn.s/cm5]	Mean ± SD	5039.10 ± 2151.52	5357.03 ± 1782.78	0.536
	Range	2869 – 13754	2540 – 9590	
	Range	6269 – 26635	7333 – 27572	

P <0.05: Statistically significant. CI: Cardiac index, CO: Cardiac output, HRV: Heart rate variability, ICON: Index of contractility, LVET: Left ventricular ejection time, PEP: Pre-ejection period, SI: Stroke index, SV: Stroke volume, SVR: Systemic vascular resistance, SVV: Stroke volume variation, TFC: Thoracic fluid content.

Table 3. Correlation between initial ICON parameters in the RD group and at 2 hours of life.

ICON Parameters		First assessment No. = 30	Second assessment No. = 30	P value
HRV	Median (IQR)	19 (9.1 - 35)	11.5 (6 - 17)	0.030*
	Range	3.4 – 867	3.6 – 142	
Blood flow				
CI [ml/min]	Median (IQR)	0.31 (0.28 - 0.42)	0.3 (0.25 - 0.37)	0.033*
	Range	0.19 – 4.6	0.15 – 3.8	
CO [ml/min]	Mean ± SD	0.94 ± 0.33	0.88 ± 0.31	0.149
	Range	0.26 – 1.72	0.22 – 1.68	
SV [ml]	Mean ± SD	6.76 ± 2.27	5.91 ± 1.62	0.016*
	Range	2.69 – 13.4	2.93 – 8.9	
SI [ml/m2]	Mean ± SD	2.20 ± 0.64	1.94 ± 0.40	0.017*
	Range	1 – 3.93	1 – 2.66	
Fluid status				
TFC	Mean ± SD	83.63 ± 26.99	79.37 ± 28.44	0.407
	Range	40 – 155	37 – 182	
SVV [%]	Mean ± SD	24.08 ± 9.33	26.90 ± 12.70	0.361
	Range	8.5 – 47	10 – 69	
Contractility				
PEP [ms]	Mean ± SD	91.20 ± 19.71	92.63 ± 23.85	0.771
	Range	43 – 152	59 – 158	
ICON	Mean ± SD	118.12 ± 63.05	103.51 ± 39.69	0.130
	Range	25.3 – 306.6	39.3 – 2 09	
LVET [ms]	Mean ± SD	169.87 ± 36.83	160.97 ± 29.79	0.199
	Range	124 – 310	74 – 234	
Vascular system				
SVR [dyn.s/cm5]	Mean ± SD	5357.03 ± 1782.78	5537.77 ± 1824.18	0.456
	Range	2540 – 9590	3179 – 10474	

*P-value <0.05: Significant. CI: Cardiac index, CO: Cardiac output, HRV: Heart rate variability, ICON: Index of contractility, LVET: Left ventricular ejection time, PEP: Pre-ejection period, SI: Stroke index, SV: Stroke volume, SVR: Systemic vascular resistance, SVV: Stroke volume variation, TFC: Thoracic fluid content.

Discussion

Electric cardiometry was not discriminatory at 10 minutes of life of the full term newborn between those in RD and those who are not. Hemodynamic monitoring in the transition from fetal to neonatal circulation is particularly challenging given the presence of complex physiological changes during this critical period of life. Understanding early neonatal cardiovascular changes is warranted to detect hemodynamic instability in time (*13*). The poor discriminatory value of EC at 10 minutes might be related to the later onset i.e. beyond 10 minutes of life of hemodynamic instability among full terms in RD. We have not compared the EC to contemporary echocardiography to asses sensitivity and specificity of EC in detection of hemodynamic instability, hence we cannot judge the sensitivity and specificity of EC as a tool for assessment of hemodynamic instability, but we report that it has no role in the early prompt diagnosis of hemodynamic instability among the full term neonates with RD.

Despite the lack of significant difference in hemodynamic parameters between those with RD and the control group within the first hour of life, yet at 2 hours of life the EC parameters; cardiac index (CI), stroke volume (SV) and stroke index (SI) significantly decreased in those with RD. These changes may be due to the gradual decrease in left ventricular preload in combination with the closure of the duct or other left-to-right shunts. We did not perform a second assessment in the control group so we cannot not verify if these EC changes were statistically different than those encountered in healthy newborns. Hence we cannot draw a conclusion that the 2 hours of life readings among those with RD were related to the RD, especially that it is already known that CO decreases significantly after 2 hours of life (*14*). Yet, studying the sensitivity and specificity of EC was out of scope of this study. The EC changes encountered in those with RD was not different among those who recovered shortly and those who needed further NICU care.

The EC at 2 hours of life was not predictive of outcome among those with RD, in contrast to the study by Paviotti and coworkers who have reported a significant increase of TFC in infants with respiratory distress at birth (*15*).

EC is increasingly studied in the neonatal field, especially in the care of critically ill neonates (*16*). EC has a reported 42% mean percentage error (*9*). In a previous study at our center, agreement between echocardiography and ICON was within the accepted range [bias < 10% and mean percentage error (MPE) < 30%)] in full-term babies (*17*). It is not interchangeable with echocardiography because of the wide range of mean percentage errors (*9*), its use for monitoring changes in cardiac parameters over time is limited and not reliable (*10*), and our work deems EC discriminatory role in predication of outcome to be limited. We did not study its role as a follow up tool, during the NICU stay or a guide for intervention among those in need of inotropes or otherwise as it was beyond the scope of our study.

Caesarian section was the mode of delivery among 90% of those with RD. Labor and delivery enhance neonatal lung adaptation by inducing catecholamines release that inhibits lung fluid secretion and stimulates surfactant. This perinatal catecholamines surge is much lower in infants born by CS (*18*), that may be responsible for the high risk of developing neonatal respiratory morbidities associated with CS (*19*, *20*).

Many types of labor anesthesia and analgesia had been increasingly used. Systemic drugs given to the mother affect the baby directly (placental transfer) while regional (spinal) analgesia affects the baby indirectly (by causing maternal hypotension) (*21*). In this study, 80% of mothers whose infants had RD received spinal analgesia while 10% received general anesthesia. Regarding the control group, none of the mothers received general anesthesia while 47% did not receive analgesia during labor. It seems that the effects of anesthesia are overlooked or underestimated. More are needed to address how to reduce anesthesia associated RD in newborns.

Conclusion

Hemodynamic parameters assessed by electric cardiometry of full term neonates within 10 minutes of birth was not different among those with RD and those without. Electric cardiometry at 2 hours of life of those with RD was not predictive of outcome.

Author Contributions: All authors searched medical literature, databases, conceptualized, conducted the case review and reviewed the final manuscript. All authors have read and agreed to the published version of the manuscript.

FUNDING

Authors declare there was no extramural funding provided for this study.

CONFLICT OF INTEREST

The authors declare no conflict of interest in connection with the reported study. Authors declare veracity of information.

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