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Electrical Cardiometry and Near-Infrared Spectroscopy During Transfusion: A Prospective Observational

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BACKGROUND

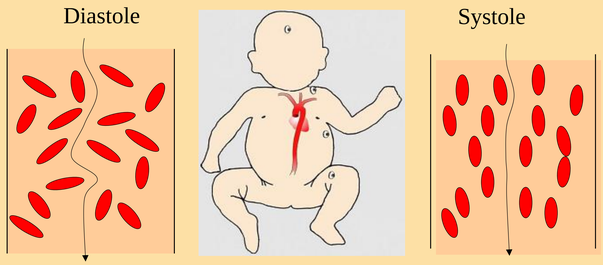
- Premature infants experience more short-term and long-term morbidities and higher mortality than other hospitalized infants and children.[1-3]
- Premature infants require packed red blood cell (PRBC) transfusions, more often than any other hospitalized population.[4-6]
- Assessing hemodynamic alterations is a challenge for the bedside neonatal practitioner.
- Signs of compromise to organ perfusion such as changes in heart rate, capillary refill, and urine output occur late and these indirect measures poorly represent the dynamics of organ perfusion and blood flow.[7-8]
- The empirical research on the impact of PRBCs on the hemodynamic status of premature infants is limited.
- Published research offers some evidence supporting the association between PRBC transfusion and necrotizing enterocolitis in premature infants.[9-10]
- Neonatal transfusion guidelines remain unstandardized across practitioners and institutions and the optimal threshold for transfusion controversial.[11-13]
- Current bedside monitoring in the neonatal intensive includes heart rate, noninvasive blood pressure measurement, respiratory rate, and pulse oximeter but, does not include direct assessment of hemodynamic function or the assessment of the balance between oxygen supply and demand.[14-15]

AIM

- To compare cardiovascular function and splanchnic regional tissue oxygen saturation (A-rSO_2) patterns between anemic and non-anemic premature infants receiving PRBC transfusion using electrical cardiometry (EC) and near infrared spectroscopy (NIRS).

NULL HYPOTHESIS

- The null hypothesis was that hemodynamic measurements of premature infants with anemia who received a PRBC transfusion would not differ over time from those of a control group of non-anemic premature infants who did not receive a transfusion.



Model of Electrical Velocimetry.[16] A theoretical diagram of red blood cell orientation during diastole and systole.

METHODS

- Prospective observational study of seventy-five premature infants.
- Single-center design using a nonprobability convenience sampling method.
- All parents approached provided written informed consent.
- Institutional review board approved.
- Comparisons among 13 data points were made before, during, and after transfusion in anemic infants and over time in non-transfused premature infants (control group).
- A portable EC device was used to measure hemodynamic parameters, including those reflective of fluid, flow, and cardiovascular status, in addition to standard bedside monitoring.
- Near infra-red spectroscopy was used to measure oxygen balance using the splanchnic area. Fractional tissue oxygen extraction (FTOE) was used to evaluate oxygen balance because of the difference between adult and fetal hemoglobin (FTOE = SpO_2 - A-rSO_2/SpO_2).

Table 1: Inclusion and Exclusion Criteria (n = 75)

Inclusion Criteria	Exclusion Criteria
Infants admitted to Level III	Potential Sensor Interference
Less than 37 weeks gestation	Anasarca
Stable	Congenital anomaly
> 2 weeks of age	Hyperbilirubinemia
RR less than 70 breathes/minute	Potential Altered Perfusion
Normotensive	APGAR score less than 3 at 5 minutes
SpO2 > 85%	Congenital heart disease
Anemic	Inotropic medication
Hemoglobin ≤ 8 grams/dl	Necrotizing enterocolitis
Hematocrit ≤ 25%	Sepsis
Order for transfusion	Other Confounding Variables
	Chromosomal abnormality
	Mechanical ventilation

STATISTICAL ANALYSIS

- A random trend mixed-method model analysis of variance was used to model individual changes over time and assess the variability of measurements within and between the 2 groups.
- Statistical comparisons were made pre-transfusion, post transfusion, and between groups over time of the following measurements: systolic and diastolic blood pressure (BP), cardiac output (CO), heart rate (HR), heart rate variability (HRV), heart rate complexity (HRC), respiratory rate (RR), saturated pulse oximeter (SpO_2), stroke volume (SV), thoracic fluid content (TFC) and A-rSO_2.
- All tests were preformed at the nominal α level of 0.5.
- Statistical analysis were preformed with statistics software (SAS 9.4, SAS Institute Inc).
- Reliability was assessed between users by using intra-class correlation to calculate consistency among observational data provided by multiple trained data collectors. The ICC was set at greater than 0.90.

RESULTS

- Splanchnic A-rSO_2 measurements increased significantly over time in the transfused group from 30 minutes (mean, 42%) to 210 minutes (mean, 78.3%). An inverse correlation in FTOE occurred over time during PRBC transfusion.
- Statistically significant differences were found in heart rate, blood pressure, respiratory rate, oxygen saturation, cardiac output, HRV, HRC, SV, TFC, and A-rSO_2.

Table 2: Patients' Demographic and Clinical Data (n = 75)

Characteristics	No transfusion (n = 40); Mean (SD) or %	Transfusion (n = 35); Mean (SD) or %	*P* value
Day of life	30.7 (32.8)	25.4 (16.9)	.39
Adjusted gestational age, weeks	33.5 (3.0)	32.9 (1.6)	.28
Birth weight, grams	1306 (592)	1305 (400)	.99
Current weight, grams	1864 (442)	1615 (323)	.13
Sex			
Male	45%	49%	.76
Vaginal Delivery	58%	40%	.17
White	25%	31%	.20
African American	37%	63%	.20
Hispanic	18%	3%	.20
Asian	20%	3%	.20
No previous transfusion	65%	80%	.07
Appropriate for gestational age	83%	91%	.30

Table 3: Post-Transfusion Comparison (n=75)

Variable	No Transfusion (n=40) Mean (SD)	Transfusion (n=35) Mean (SD)	*P* value
HR, beats/minute	155.7 (9.3)	140.5 (9.47)	< **.001**
Systole BP, mm HG	55.3 (7.02)	70.2 (6.99)	< **.001**
Diastolic BP, mm Hg	32.1 (4.80)	33.8 (4.85)	< **.001**
RR, breaths/minute	48.7 (5.88)	40.4 (6.16)	< **.001**
SpO_2, %	96.5 (2.1)	99.0 (2.25)	< **.001**
Cardiac Output, L/min	0.23 (0.04)	0.27 (0.04)	< **.001**
HRV	16.0 (10.4)	25.0 (10.4)	< **.001**
HRC	0.47 (0.25)	0.69 (0.24)	< **.001**
Stroke volume, ml	1.5 (0.24)	1.7 (0.24)	< **.001**
TFC	20 (8.2)	28.4 (8.2)	< **.001**
A-rSO_2, %	36.2 (4.7)	78.5 (7.9)	< **.001**

DISCUSSION

- Cardiovascular function and A-r$S0_2$ changed over time with transfusion and were outside the reference ranges for infants regardless of gestational age.
- During PRBC transfusion premature infants experience changes in cardiovascular function and A-rSO_2 over time that are not captured during standard physiologic monitoring.

CONCLUSIONS

- Bedside monitoring using EC and NIRS during PRBC transfusion may inform individualized care for the anemic premature infant and be useful in the development of evidence based guidelines.