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Cerebral oxygenation during the period of transition to extrauterine life after natural versus cesarean birth

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Abstract

Objective. *We aim to evaluate the implications of cesarean delivery compared to natural birth by analyzing newborns' systemic and cerebral oxygenation levels during the first 10 minutes of life.*

Design. *This paper presents a 4-year prospective cohort study.*

Setting. *Polizu Maternity, "Alessandrescu-Rusescu" National Institute for Mother and Child's Protection, Bucharest, Romania.*

Patients. *Randomly selected pregnant women and their fetuses.*

Interventions. *During the 10 min following umbilical cord clamping, regional cerebral oxygen saturation (rcSO2) was measured using the INVOS 5100 device and peripheral oxygen saturation (SpO2) was determined using the Masimo SET pulse oximeter in neonates from cesarean and natural deliveries.*

Main outcome measures. *The cerebral fractional tissue oxygen extraction (cFTOE) in the first 10 minutes of life was calculated based on these values.*

Results. *Newborns delivered vaginally showed higher $rcSO_2$ levels at 1 minute of life than those born via C-section (40.5 ± 16.5% vs 33.7 ± 14.8%, AUC = 0.625; IC 95%: 0.506 - 0.743; p = 0.043). Neonatal cFTOE at 1 minute of life was significantly higher in caesarean-delivered newborns versus naturally born neonates (0.40 ± 0.25 vs 0.50 ± 0.19, p = 0.03; AUC = 0.638; IC 95%: 0.517-0.758; p = 0.023).*

Conclusions. *Prelabor cesarean delivery seemingly plays a significant role in the process of fetal and neonatal cerebral oxygenation immediately postnatally, which is highlighted by lower $rcSO_2$ and higher cFTOE values. Cerebral oxygen saturation monitoring in the delivery room allows the optimization of oxygen therapy in order to prevent the consequences of hypoxia or hyperoxia.*

Keywords: cerebral oxygenation, NIRS, natural delivery, cesarean section

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INTRODUCTION

Nowadays, when both doctors and patients are increasingly opting for cesarean deliveries, we aim to evaluate the benefits and risks of this type of delivery. We mainly analyzed the effects on systemic and cerebral oxygenation levels in the first 10 minutes of life.

The transition to extrauterine life is a complex physiological process. The newborn's adjustment to extrauterine life immediately after birth is currently evaluated based on the clinical exam [1]. The clinical aspects that are examined are those that comprise the Apgar score (appearance, pulse, grimace, activity and respiration; however they are highly subjective [2]. Clinical examination together with markers like umbilical cord and scalp pH offer reduced sensitivity and specificity in the prediction of short and long-term neurodevelopmental difficulties [3, 4]. Thus, an early predictor of perinatal brain injury severity is still under investigation. The value of this marker lies in the need to detect cases of perinatal asphyxia that can benefit from current therapeutic interventions [5]. The sooner neuroprotective therapy is initiated, the greater the benefits [6].

One should be able to take advantage of a real-time predictive marker that can aid in timely decision-making. Cerebral oxygenation in neonates can currently be evaluated in neonatal intensive care units using in vivo NIRS (Near Infrared Spectroscopy) technology. In the present study, we plan to extend these measurements to the delivery room in the transition period. It is known that the fetus is adapted to a moderately hypoxic environment and that, at the time of birth their partial pressure of oxygen in the blood reaches low values [7]. After birth, in the first 10 minutes of life, neonatal peripheral oxygen saturation shows steadily increasing values [8,9]. Recognizing the dynamics of cerebral oxygen saturation during the first 10 minutes of life can provide useful information regarding neonatal adaptation and perinatal suffering. This data can contribute to therapeutic decisions made right in the delivery room.

MATERIAL AND METHODS

A prospective study was conducted over a 4-year period (2014-2017), where we analyzed randomly selected pregnant women and their fetuses which met our inclusion criteria.

Inclusion criteria. Maternal criteria included: a minimum age requirement of 18 years, no illnesses that may affect fetal oxygenation (cardiovascular, respiratory or renal disease, untreated diabetes), gestational age (GA) greater than 36 weeks and no clinical and/or biological evidence of chorioamnionitis such as affected fetal heart rate (FHR), leukocytosis, fever.

Exclusion criteria. Newborns were excluded if they associated congenital malformations of the central nervous system, cranial malformations diagnosed or suspected in the antenatal or postnatal period, systemic disorders (hydrops fetalis, pleural effusions, ascites, hemolysis/anemia) or if they had a Ballard score of fewer than 36 weeks.

In the first 10 minutes of life, all newborns were evaluated by a neonatologist. After birth, the newborns were placed on an infant radiant warmer with the head and neck in a slightly extended position. The blood and vernix were rinsed off from the forehead and right hand so that the two sensors could be applied. The first sensor, monitoring regional cerebral oxygen saturation (rcSO2) through the NIRS technique using the INVOS 5100 device (Covidien, USA), was placed on the left side of the forehead. The second sensor, measuring peripheral oxygen saturation (SpO2) using the Masimo SET pulse oximeter (Masimo Corporation, Irvine, CA, USA), was placed on the right hand (pre-ductal). They were maintained for reading and recording of saturation from about 1 to 10 minutes after birth. Patient maneuvering was maintained to a minimum in order to avoid artifacts. Based on rcSO2 and SpO2 values, the cerebral fractional tissue oxygen extraction (cFTOE) in the first 10 minutes of life was also calculated.

All measurements were recorded in the first 10 minutes of life both electronically and manually in a special individual sheet. All NIRS analysis was conducted by the same data collection team that was not involved in the newborns' care.

Data quality criteria. SpO2, which measures oxygenated arterial hemoglobin, is physiologically higher than rcSO2, which measures the hemoglobin saturation levels primarily at venous level (75% venous, 20% arterial and 5% capillary saturation levels). Cases, where rcSO2 values were greater than or equal to those of SpO2, were considered non-physiological and improperly measured, and therefore were excluded from the study. This approach has significantly increased the accuracy of data while eliminating artifacts.

Data analysis. All NIRS and SpO2 measurements were individually evaluated. cFTOE in the first 10 minutes of life was calculated according to the formula: cFTOE = (SaO2-rcSO2)/SaO2. Percentiles 25-75 and median values for rcSO2 and cFTOE were also calculated. The data was systematized and centralized into an SPSS 18.0 database and processed using proper statistical functions. A 95% confidence level was used in the data presented. The descriptive statistical analysis was performed using the ANOVA test.

Study group. The study group consisted of 119 full-term newborns from our clinic between 2014 and 2017. Out of the total number of newborns monitored by NIRS and pulse oximetry, 9 were excluded since they associated rcSO2 levels that were greater than or equal to those of SpO2. 15 other cases were removed as a result of medication or interventions that could alter rcSO2 or SpO2, such as oxygen administration to the newborn in the first 10 minutes of life (5 cases), oxygen administration to the mother during labor and/or fetal expulsion (4 cases), maternal administration of Entonox, a combination of nitrous oxide 50% and oxygen 50% (2 cases), the cesarean section with general anesthesia and oxygen administration FiO2 50% (2 cases), maternal antenatal and newborn oxygen administration (1 case) and forceps delivery (1 case).

The study was approved by the Local Ethics Committee: Research and Development Ethics Committee of "Alessandrescu-Rusescu" National Institute for Mother and Child Health, Polizu, Bucharest, approval ID no 13289/08.09.2017. Verbal and written consent for participation in the study and data use was obtained before giving birth.

RESULTS

A total of 95 newborns were analyzed, 39 of which were born naturally and 56 via cesarean section. It should be noted that cesarean surgery was performed during early labor or in the absence of it.

Peripheral oxygen saturation levels increase in the first 10 minutes of life in full-term newborns who don't require respiratory support or supplemental oxygen. SpO2 values rose from 65.97 ± 13.64% at 1 minute of life to 94.74 ± 4.18% at 10 minutes of life. A significant increase in rcSO2 values was also noticed, namely from 36.47 ± 15.84% at 1 minute of life to 63.32 ± 14.03% at 5 minutes of life and 76.71 ± 9.56% at 10 minutes of life (Table 1).

TABLE 1. *Regional cerebral oxygen saturation (rcSO2) in the first 10 minutes of life in full-term newborns with physiological postnatal adaptation*

rcSO2 (%)		**1 min**	**5 min**	**10 min**
N		95	95	95
Mean		*36.47*	*63.32*	*76.71*
Median		*35.50*	*65.00*	*77.00*
Standard Deviation		15.84	14.03	7.33
Variance		43.43	22.16	9.56
Skewness Test		0.249	0.689	0.349
Skewness Standard Error		0.251	0.247	0.249
Minimum		15	19	60
Maximum		81	95	91
Percentiles	10	15.00	42.60	65.50
	25	24.00	56.00	70.75
	50	35.50	65.00	77.00
	75	45.00	72.00	82.00
	90	58.80	80.00	85.50

A serious decrease in cFTOE values during the transition period was observed, namely from 0.456 ± 0.227 at 1 minute of life to 0.236 ± 0.144 at 5 minutes of life and 0.199 ± 0.114 at 10 minutes of life (Table 2).

TABLE 2. *Cerebral fractional tissue oxygen extraction (cFTOE) in the first 10 minutes of life in full-term newborns with physiological postnatal adaptation*

Extraction fraction		**1 min**	**5 min**	**10 min**
Number of cases		95	95	95
Mean		0.456	0.236	0.199
Median		0.450	0.220	0.190
Standard Deviation		0.227	0.144	0.114
Variance		0.051	0.021	0.013
Skewness Test		0.136	0.927	1.746
Skewness Standard Error		0.247	0.247	0.249
Minimum		0.07	0.03	0.02
Maximum		0.80	0.73	1.00
Percentiles	10	0.162	0.070	0.100
	25	0.300	0.130	0.130
	50	0.450	0.220	0.190
	75	0.620	0.290	0.253
	90	0.742	0.438	0.300

The type of birth consequences on cerebral oxygenation was analyzed by comparing two groups of full-term newborns: one with neonates born naturally (n = 39) and another with infants born by cesarean section (n = 56).

The epidemiological characteristics of the two groups were systematized in Table 3.

TABLE 3. *Characteristics of the two groups of newborns by birth type: vaginal versus cesarean delivery*

Birthway	**Total group**	**Spontaneous (39 cases)**	**Caesarean (56 cases)**	**p value**
GA	38.58 ± 0,93 wk	38.5 wk	38.5 wk	n.s.
BW	3350 ± 395 g	3360.4 g	3359.2 g	n.s.
AS	8.56 ± 0.71	8.5	8.5	n.s.
Gender	45.3% male	38.4 % male	44.6% male	n.s.

GA – gestational age; BW – birth weight; AS – Apgar score; wk – week

Statistical indicators of oxygenation parameters (rcSO2, SpO2 and cFTOE) compared to birth types are shown in Tables 4, 5 and 6.

Mean values of rcSO2 at 1 minute of life were significantly lower in cesarean vs spontaneous delivery, measuring 33.75 and 40.51 respectively, p = 0.044. It would seem that SpO2 values were not greatly influenced by the type of delivery throughout the transition to extrauterine life. However, cFTOE was considerably higher in cesarean delivery vs spontaneous birth at 1 minute of life, with mean values measuring 0.50 and 0.40 respectively, p = 0.036.

When plotting the ROC curve, it was revealed that opting for cesarean section greatly influenced fetal and neonatal cerebral saturation levels at 1 minute of life, with area under the curve (AUC) measuring 0.625, confidence interval (CI) 95%: 0.506-0.743, p = 0.043 (Figure 1).

***TABLE 4.** Statistical indicators of regional cerebral oxygen saturation (rcSO2) by birth type*

rcSO2		After cesarean section			After spontaneous vaginal delivery		
		1 min	5 min	10 min	1 min	5 min	10 min
Number of cases		56	56	55	39	39	39
Mean		33.75	62.61	76.59	40.51	64.33	76.89
t-Student $_{\text{c-sections spontaneous delivery}}$					p=0.044	p=0.558	p=0.844
Median		35.00	64.50	77.00	40.00	67.00	78.00
Standard Deviation		14.88	13.10	7.05	16.55	15.38	7.82
Variance		44.09	20.92	9.20	40.85	23.91	10.17
Skewness Test		0.731	-0.736	0.228	0.293	-0.721	-0.507
Skewness Standard Error		0.322	0.319	0.319	0.388	0.378	0.383
Minimum		15	25	61	15	19	60
Maximum		79	86	89	81	95	91
Percentiles	10	15	42	26	56	72	88
	20	19	51	33	60	75	93
	25	21	55	39	63	77	93
	30	24	57	40	67	78	94
	40	26	62	44	69	80	95
	50	35	65	50	70	81	96
	60	36	68	51	75	81	97
	70	40	70	52	76	83	97
	75	43	71	68	81	87	98
	80	45	72	83	77	89	98
	90	56	79	85	81	91	99

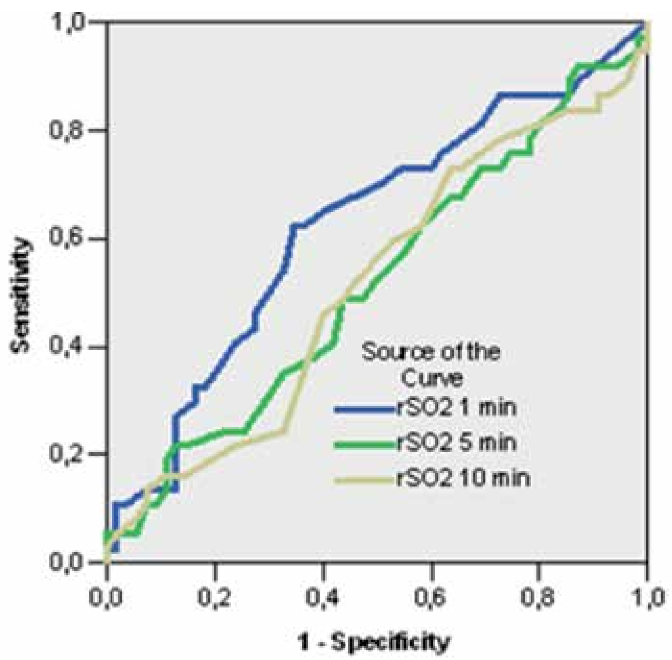
***TABLE 5.** Statistical indicators of peripheral oxygen saturation (SpO2) by birth type*

SpO2		After cesarean section			After spontaneous vaginal delivery		
		1 min	5 min	10 min	1 min	5 min	10 min
Number of cases		56	56	55	39	39	39
Mean		65.77	82.64	94.84	66.26	82.46	94.62
t-Student $_{\text{c-section}vs\text{ spontaneous delivery}}$					p=0.865	p=0.918	p=0.802
Median		70.00	84.00	95.00	68.00	82.00	96.00
Standard Deviation		12.50	8.91	3.61	15.30	7.66	4.92
Variance		19.01	10.78	13.03	23.09	9.29	5.20
Skewness Test		-0.482	-0.316	-1.395	-0.713	-0.010	-2.395
Skewness Standard Error		0.319	0.319	0.322	0.378	0.378	0.378
Minimum		40	63	85	14	64	74
Maximum		90	97	100	98	100	100
Percentiles	10	45	70	90	50	74	88
	20	51	73	93	53	76	93
	25	58	75	94	55	78	93
	30	61	77	94	57	79	94
	40	65	82	95	64	80	95
	50	70	84	95	68	82	96
	60	71	86	96	74	85	97
	70	73	89	97	75	86	97
	75	75	90	97	76	88	98
	80	77	92	98	77	89	98
	90	80	94	98	81	91	99

ROC curve plotting further revealed that cesarean delivery significantly affected fractional oxygen extraction at fetal and neonatal cerebral levels in the first minute of life (AUC = 0.638; CI 95%: 0517-0758; p = 0.023) (Figure 2).

***TABLE 6.** Statistical indicators of the cerebral fractional tissue oxygen extraction (cFTOE) by birth type*

cFTOE		**After caesarean section**			**After spontaneous vaginal delivery**		
		1 min	**5 min**	**10 min**	**1 min**	**5 min**	**10 min**
Number of cases		56	56	55	39	39	39
Mean		0.50	0.24	0.19	0.40	0.23	0.21
t-Student $_{CS\ vs\ SVD}$					p=0.036	p=0.559	p=0.610
Median		0.50	0.24	0.19	0.33	0.20	0.19
Standard deviation		0.19	0.14	0.07	0.25	0.15	0.15
Variance		0.04	0.02	0.01	0.06	0.02	0.02
Skewness Test		0.044	0.531	0.027	0.643	1.471	3.681
Skewness Test Error		0.319	0.319	0.322	0.378	0.378	0.378
Minimum		0.11	0.03	0.04	0.04	0.04	0.02
Maximum		1.00	0.64	0.34	1.00	0.73	1.00
Percentiles	10	0.23	0.05	0.11	0.08	0.07	0.08
	20	0.33	0.10	0.11	0.17	0.10	0.11
	25	0.37	0.13	0.13	0.20	0.12	0.12
	30	0.39	0.17	0.15	0.26	0.14	0.14
	40	0.43	0.22	0.17	0.30	0.15	0.18
	50	0.50	0.24	0.19	0.33	0.20	0.19
	60	0.56	0.27	0.21	0.40	0.22	0.20
	70	0.60	0.29	0.24	0.55	0.24	0.22
	75	0.64	0.33	0.26	0.59	0.26	0.23
	80	0.67	0.35	0.28	0.66	0.29	0.28
	90	0.76	0.42	0.29	0.73	0.46	0.32



Area Under the Curve

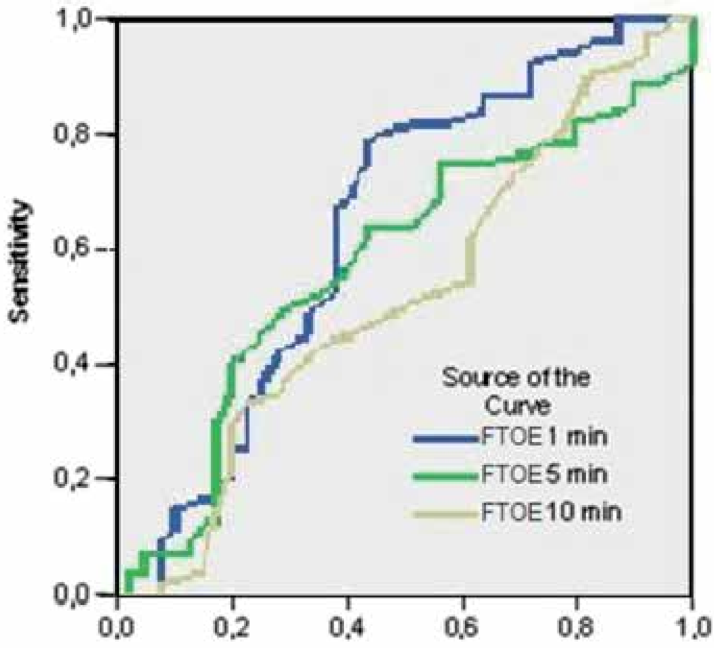
Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
rSO2 1 min	,625	,060	,043	,506	,743
rSO2 5 min	,519	,062	,756	,397	,641
rSO2 10 min	,515	,062	,808	,393	,637

The test result variable(s): ScO2 1 min, ScO2 5 min, ScO2 10 min has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

FIGURE 1.



Area Under the Curve

Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
FTOE 1 min	,638	,062	,023	,517	,758
FTOE 5 min	,573	,061	,228	,454	,692
FTOE 10 min	,517	,062	,782	,395	,638

The test result variable(s): ScO2 1 min, ScO2 5 min, ScO2 10 min has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

FIGURE 2.

DISCUSSIONS

Reference values for regional cerebral oxygen saturation and cerebral fractional tissue oxygen extraction in full-term neonates during the period of transition to extrauterine life

All newborns showed a gradual increase in rcSO2 values along with SpO2 levels, starting from an average of 36.47 ± 15.84% at 1 minute of life, rising to 63.3 ± 14.0% at 5 minutes and reaching peak values of 76.71 ± 9.56% at 10 minutes of life (Table 1). cFTOE had a downward trend in the first ten minutes of life. These results can help define reference values of rcSO2 and cFTOE in full-term neonates during the period of transition to extrauterine life, as suggested in Table 7.

Up to the present, the sole knowledge of SpO2 values in the first 10 minutes of life did not influence the management of newborns in the delivery room. As a result, no significant reduction in pathologies caused by hypoxia or hyperoxia (e.g. chronic pulmonary disease, retinopathy of prematurity) was noted [10,11]. Therefore, we consider that establishing reference values for regional oxygen saturation, in this case at the cerebral level, and measuring them in real-time in the delivery room, can optimize postnatal oxygen therapy. These measurements might prevent the effects of hypoxia and/ or hyperoxia caused by an inadequate administration of oxygen.

Type of delivery and postnatal cerebral oxygenation

Exploring the influence of birth type on cerebral oxygenation, it was observed that neonates born by vaginal delivery (group A = 39 cases), when compared to those born via cesarean section (group B = 56 cases) requiring no resuscitation at birth, had rcS02 values significantly higher at 1 minute of life, namely 40.5% vs

***TABLE 7.** Regional cerebral oxygen saturation percentiles and peripheral capillary oxygen mean values during the first 10 minutes of life in full-term newborns that do not require respiratory support*

		rcSO2			cFTOE		
Minutes of life		1 min	5 min	10 min	1 min	5 min	10 min
Mean		36.47	63.32	76.,71	0.,45	0.23	0,19
Median		35.50	65.00	77.00	0.45	0.22	0.19
Minimum		15	19	60	0.07	0.03	0.02
Maximum		81	95	91	0.80	0.73	1.00
Percentiles	10	15.00	42.60	65.50	0.16	0.07	0.10
	25	24.00	56.00	70.75	0.30	0.13	0.13
	50	35.50	65.00	77.00	0.45	0.22	0.19
	75	45.00	72.00	82.00	0.62	0.29	0.25
	90	58.80	80.00	85.50	0.74	0.43	0.30

***TABLE 8.** Cerebral oxygen saturation (rcSO2) and cerebral fractional tissue oxygen extraction (cFTOE) of vaginal (Sp - spontaneous) newborns as compared to those delivered by caesarean section (Cse)*

Parameters		rcSO2						cFTOE					
Age		1 min		5 min		10 min		1 min		5 min		10 min	
Birth type		Sp	Cse	Sp	Cse	Sp	Cse	Sp	Cse	Sp	Cse	Sp	Cse
Mean		40.5	33.7	64.3	62.6	76.9	76.6	0.40	0.50	0.23	0.24	0.21	0.19
Median		40.0	35.0	67.0	64.5	78.0	77.0	0.33	0.50	0.20	0.24	0.19	0.19
Minimum		15	15	19	25	60	61	0.04	0.11	0.04	0.03	0.02	0.04
Maximum		81	79	95	86	91	89	1.00	1.00	0.73	0.64	1.00	0.34
Percentile	10	56	15	72	42	88	26	0.08	0.23	0.07	0.05	0.08	0.11
	25	63	21	77	55	93	39	0.20	0.37	0.12	0.13	0.12	0.13
	50	70	35	81	65	96	50	0.33	0.50	0.20	0.24	0.19	0.19
	75	81	43	87	71	98	68	0.59	0.64	0.26	0.33	0.23	0.26
	90	81	56	91	79	99	85	0.73	0.76	0.46	0.42	0.32	0.29

35.7% (p = 0.044). The aforementioned high values noticed in natural births were not accompanied by a significant increase in SpO2 levels. This confirms that rcSO2 is not determined solely by arterial O2 concentration. Cerebral oxygenation also depends on other factors such as oxygen supply, which in turn, is influenced by cerebral blood flow (CBF) [12,13]. A notable increase of CBF in the middle cerebral artery (MCA) was observed in the first 4 minutes of life, as evidenced by an important decrease in the MCA pulsatility index (PI) after uncomplicated labor. Studies in full-term neonates show that CBF velocity decreases in the first 30 minutes [14] of life while the cerebrovascular PI increases, suggesting a raise in resistance [15,16]. It is currently not known whether CBF is influenced by the type of birth [17,18]. These facts reveal that the process of physiological labor during vaginal delivery prepares the fetus for expulsion (at a time when oxygen and blood supply will be minimal) through circulatory changes of the cerebrovascular system that provide adequate blood and oxygen supply in the cerebral tissue. Neonates delivered by cesarean section are associated with significantly increased cFTOE values at 1 minute of life compared to those born vaginally (0.50 vs 0.40, p = 0.036), further confirming that the main adaptive mechanisms of birth, which associates transient physiological hypoxia, are not triggered during cesarean surgery. Therefore, at the time of delivery, the only remaining mechanism of adjusting to hypoxia is that of increasing oxygen extraction in cerebral tissue. The difference in cFTOE values between the two types of delivery could be absent in the case of cesarean sections preceded by the occurrence of labor. Some recent studies showed insignificant differences between the two types of delivery regarding rcSO2 and neonatal cFTOE values at 1 minute of life [19,20]. Contradictory results in the present study could be attributed to the lack of sufficient uterine contractions before undergoing cesarean section in the studied cases.

SpO2 and heart rate are subjected to changes during the transition to extrauterine life period and are significantly higher in neonates delivered naturally. In an ample recent study, higher statistically significant values of rcSO2 after natural birth at 1 minute of life (similar to our study) and 5 minutes of life compared to those following caesarean extraction were observed [19]. Knowledge of the factors that influence cerebral tissue oxygenation is necessary in order to correctly assess rcSO2 values detected immediately postnatally. Cerebral oxygen saturation mainly depends on oxygen supply and consumption in the brain. Cerebral oxygen supply is determined by oxygen saturation and cerebral blood flow [21].

Oxygen saturation is relevant for the illustration of oxygen intake in the cerebral circulation and it is assessed by pre-ductal oxygen saturation. It highly dependent on hemoglobin count (both oxygenated and deoxygenated) and blood factors that influence the binding of oxygen to hemoglobin (such as pCO2, pH, temperature and pO2). CBF depends on cardiac output (CO), cerebral vascular resistance (CVR) and the persistence of fetal shunts- ductus arteriosus and foramen ovale - during the transition period [18, 22]. The shunt through the ductus arteriosus rapidly changes postnatally, attaining a left-to-right direction that increases CO [23,24]. These hemodynamic changes influence cerebral oxygenation, with higher values of cerebral rS02 being observed in patients with shunting compared to those with no shunts [22]. Cerebral oxygenation is modified by shunts through the cerebral flow which is inversely proportional to the sum of the diameters of the ductus arteriosus and foramen ovale [23,25].

In the case of physiological adaptation, based on changes in total hemoglobin evaluated by NIRS, it was noted that cerebral blood volume significantly decreases immediately after birth. Increased arterial oxygen pressure after birth leads to cerebral vasoconstriction which could explain the reduction in cerebral blood volume that may be considered physiological [26,27]. These modifications reveal that antenatally, the fetus has a higher physiological cerebral circulation compared to the postnatal period due to right-to-left shunts and fetal cerebral vasodilatation that allow for optimal cerebral oxygen uptake under low fetal pO2 conditions [28]. These mechanisms are stimulated during labor with each contraction, preparing the fetus for exposure to transient hypoxia during delivery, and further amplified by the expulsion, thus preventing the decrease of CBF to hypoxic-ischemic levels [29].

The dynamics of oxygen supply and the shunts that direct the blood volume to the brain suggest that the decrease in CBF that appears right after expulsion is caused by these two factors that act either separately or combined. Therefore, arterial oxygen concentration increases and shunts diminish or switch direction to left-to-right. Cardiac output, primarily determined by heart rate that is elevated after natural birth, may be increased in these newborns, which could explain a higher CBF and a greater rcSO2 compared to neonates born by caesarean. Animal studies show that in order to maintain constant rcSO2 values, changes in arterial oxygenation cause reactive changes of CBF while changes in cardiac output do not result in CBF modifications [19]. These data along with the observation that rcSO2 differs slightly from the SpO2 difference between the two types of birth, suggests that changes in CBF are caused by the cerebral autoregulation phenomenon. Cerebrovascular autoregulation is mediated mainly by local vascular factors [30].

In this study, during the first 10 minutes of transition to extrauterine life, we noticed lower cFTOE values in the batch of births via caesarean section versus those via vaginal route, similar to the study performed by Schwaberger et al. in 2018 [31].

Below is a comparison between the two types of birth taking into account rcSO2 and cFTOE values in the first 10 minutes of life based on the results of this study (Table 8).

Urlesberger et al. recently showed that regional cerebral oxygenation rapidly changes in the first 7 minutes of life, as opposed to post-ductal or pre-ductal peripheral saturation that associates a slow increase of up to 10 minutes. Concurrently, cFTOE decreases more rapidly, reaching a plateau before peripheral FTOE. It was also noticed that rcSO2 values increase faster, entering the plateau phase quicker than SpO2 [31]. These observations indicate that in the immediate period of transition to extrauterine life, oxygen supply is preferentially directed to the cerebral level [32]. Therefore we can deduce that, in case of fetal distress, the first response mechanisms happen at cerebral level (hemodynamic, metabolic and electrical activity) and thus immediate postpartum cerebral monitoring could promptly reveal the hypoxic-ischemic attack.

CONCLUSIONS

Regional cerebral oxygen saturation as well as blood oxygen saturation had an upward trend over the first 10 minutes of life, starting from an average of 36.4 ± 15.8% at 1 minute life to 63.3 ± 14.0% at 5 minutes and finally reaching 76.71 ± 9.5% at 10 minutes of life (p = 0.007). Newborns with physiological adaptation showed higher rcSO2 levels at 1 minute of life when delivered vaginally than those born via cesarean section (40.5 ± 16.5% vs 33.7 ± 14.8%, AUC = 0.625; IC 95%: 0.506 - 0.743; p = 0.043).

Cerebral fractional tissue oxygen extraction, reflecting metabolic rate, displayed a downward trend after birth from mean values of 0.45 ± 0.22 at 1 minute of life to an average of 0.23 ± 0.14 at 5 minutes of life and reached stable values of 0.19 ± 0.11 at 10 minutes of life (p = 0.001). Neonatal cFTOE at 1 minute of life was significantly higher in caesarean-delivered newborns versus naturally born neonates (0.40 ± 0.25 vs 0.50 ± 0.19, p = 0.03; AUC = 0.638; IC 95%: 0.517-0.758; p = 0.023).

Cesarean section in the absence of labor is likely to have a significant role in the process of fetal and neonatal cerebral oxygenation immediately postnatally, which is evidenced by lower rcSO2 and higher cFTOE values compared to those from naturally delivered neonates.

Cerebral oxygen saturation monitoring in the delivery room according to percentiles that we proposed in the present study allows the optimization of oxygen therapy in order to prevent the consequences of hypoxia or hyperoxia.

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