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SpO_2, heart rate, and arterial blood pressure during successful or failed application of non-invasive ventilation after delivery – a single-centre study

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Abstract

Background: SpO_2, heart rate, and systolic, diastolic, and mean arterial blood pressure are among the commonly applied and most frequently chosen indicators of well-being of newborns in intensive care units. Objective: to determine the relationship between the aforementioned parameters and the status of newborns depending on the outcome of the Infant Flow (I-F) therapy, and the development of complications in the form of pneumothorax.

Methods: A retrospective single-centre study covering the years 2009–2014. A total of 182 neonates, with mean gestational age 34.1 weeks and mean body weight 2226 g, were analysed. The minimum and maximum values of the evaluated parameters were analysed statistically according to the therapy outcome noted as success or failure.

Results: A successful outcome of I-F therapy (71.4%) was characterised by higher SpO_2 (93.3 ±7.28 vs. 85.9 ±14.77 at $P < 0.001$; 99.95 ±0.31 vs. 98.6 ±3.30 at $P < 0.0001$), lower heart rate (122.5 ±12.37 vs. 135.9 ±14.97 at $P < 0.0001$), and higher max systolic blood pressure (79.05 ±12.49 vs. 69.78 ±13.73 mm Hg at $P < 0.0001$), max diastolic blood pressure (57.03 ±9.31 vs. 50.41 ±13.82 mm Hg; $P < 0.0003$), and max as well as min mean arterial blood pressure (46.8 ±10.13 vs. 41.39 ±15.46 mm Hg; $P < 0.001$) (27.88 ±5.71 vs. 26.14 ±7.35 mm Hg; $P < 0.02$).

Conclusions: In newborns suffering from respiratory failure and treated with I-F, higher SpO2 values, lower heart rate, and higher arterial blood pressure coincide with success of the I-F therapy.

Key words: neonates, pneumothorax, non-invasive ventilation.

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Non-invasive ventilation has become increasingly popular and is frequently chosen before other methods of ventilation [1–6]. Such methods are used by the Infant Flow (I-F) SiPAP system, a very popular device used in Polish neonatal intensive care units (NICU).

The I-F SiPAP system is combined with a patented variable flow generator to provide non-invasive positive pressure ventilation, offering nasal continuous positive airway pressure (CPAP) and bi-level modalities. For over two decades the I-F nCPAP System has delivered gentle respiratory support to thousands of neonates worldwide [7–9]. CPAP modality uses elevated pressure (above atmospheric) to recruit collapsed alveoli and ultimately to increase functional residual capacity (FRC), thus improving gas exchange in the lungs.

CPAP is a modality used for babies with a mild/moderate need for breathing support. BiPhasic, on the other hand, is a modality used for babies that require more respiratory support than CPAP can provide. In the BiPhasic mode, respiratory rate, inspiratory time, and peak inspiratory pressures are preset and not synchronised with the breathing effort.

There are some studies on using the nCPAP in the delivery room for supporting neonates with respiratory failure (RDS), but there are only limited data about the effectiveness of biphasic pressure methods (including those offered by I-F) as the first method of respiratory support in neonates [7–10]. Zhou *et al.* demonstrated that nasal continuous positive airway pressure on two pressure levels (DuoPAP) improves oxygenation better, reduces CO_2 retention, and reduces the need for mechanical ventilation in newborns with diagnosed RDS, than does CPAP alone [7]. Rong *et al.* published similar observations indicating that BiPAP, in comparison with CPAP, significantly reduces the need for intubation in the first 72 hours of life in a group of newborns born from 26 to 32 weeks of gestation [8]. Lista *et al.* compared the results in newborns born at a gestational age from 28 to 34 weeks with a mild form of RDS treated with non-invasive ventilation from birth, stating that the bi-level method required a length of use significantly shorter than typical nCPAP and allowed shortening the stay of the newborn in the ward [11].

Percutaneous measurement of oxygen saturation (SpO_2), heart rate, systolic, diastolic, and mean arterial blood pressure, are among the commonly applied and most frequently chosen indicators of well-being for newborns in neonatal intensive care units [12, 13]. These parameters are monitored particularly in newborns with respiratory failure treated with various forms of respiratory support. The stress connected with perinatal hypoxia and developing respiratory failure may negatively impact values of those parameters [12]. Up to now there have been no reports on the behaviour of the aforementioned parameters when monitoring the status of newborns in accordance to the outcome of the I-F SiPAP therapy.

The aim of the study was to determine the relationship between SpO_2, arterial blood pressure, and heart rate and the status of newborns depending on the outcome of the I-F therapy.

METHODS

Parents of subjects gave their written informed consent. The study was approved by the Pomeranian Medical University Ethical Committee (decision No KB – 0012/45/01/2013).

A cohort retrospective study was conducted on a sample of 182 newborns (98 boys and 84 girls) hospitalised due to respiratory failure in the Pomeranian Medical University Department of Neonatology in Szczecin, Poland, between 2009 and 2014. The studied babies were treated with non-invasive ventilation from an I-F SiPAP system (CareFusion, Yorba Linda, USA) as the first form of respiratory support after delivery. The babies selected for the presented analysis included those in whom symptoms of respiratory failure were diagnosed after birth and who did not present with congenital malformations that might negatively influence the assessed parameters during I-F therapy.

The Silverman score was used to assess the severity of respiratory distress in the newborns before the decision about using I-F. The score comprises four inspiratory categories of movements (thoracoabdominal, intercostal, xiphoid, and chin movements) and one expiratory category (grunting) [14]. Surfactant was not used in any of the analysed patients before or during I-F therapy.

In the present study using the I-F type device, the preferred method was breathing using two pressure levels (Biphasic), with a lower usually set no higher than 5 cm H_2O and higher at a level 8 cm H_2O or more. Usually the lowest FiO2 necessary to maintain SpO2 at 95% was used. In 114 (62.6%) cases pharmacological sedation (pethidine) was used during I-F method application. Indications for sedation were as follows: inability to calm a newborn baby during the application of the I-F method through non-pharmacological actions. When arterial hypotension was recognised basing on mean arterial pressure (mm Hg) lower than the gestational age (weeks) of the newborn and clinical signs of poor perfusion, fluid and/or inotropes were used to correct it.

Success was noted when the baby improved and weaning from I-F was possible. Failure was recognised when deterioration in the baby's condition lead to intubation and mechanical ventilation or when pneumothorax was recognised. Indications for intubation were as follows: respiratory acidosis (pH < 7.20 and PCO_2 > 65 mm Hg), apnoea and bradycardia in spite of noninvasive ventilation, and hypoxia (PaO_2 < 50 mm Hg, SpO_2 < 87%) in spite of noninvasive ventilation with FiO_2 > 0.6 or pneumothorax.

A multifunctional Mindray iPM 12 monitor was used to monitored parameters (SpO_2, heart rate, and arterial blood pressure). During the I-F therapy, the parameters were recorded on an hourly basis from the monitor screen and registered on intensive care status charts. The minimum (min) and maximum (max) values of those parameters in individual newborns were analysed statistically for the entire analysed sample as well as for the subgroups that were divided according to the therapy outcome (success or failure), and the development of complications in the form of pneumothorax.

Statistical analysis

The obtained values of the particular parameters were compared between the subgroups with appropriate statistical analysis tools. Continuous variables were checked for normality of distribution with a Kolmogorov-Smirnov test. Median, minimum, and maximum values were used to describe the variables (in cases when the normal distribution assumptions were not met), while in other cases the mean and standard deviation were calculated. Discrete variables were described by the frequency of their occurrence (number, percentage). χ^2 Pearson, χ^2 Yates, and χ^2 NW tests were used to study statistical differences or to check the homogeneity of the groups. Statistical differences between continuous variables of the different groups were checked with a Mann-

TABLE 1. Mean, minimum, and maximum values of saturation (Sp02), heart rate, and blood pressure in the all analysed groups of neonates

Features	*n*	Mean	Min	Max	SD
SpO_2 min	182	91.22	38.00	100.00	10.51
SpO_2 max	182	99.56	83.00	100.00	1.87
HR min	182	126.40	78.00	168.00	14.45
HR max	182	167.29	133.00	220.00	15.49
SBP min	182	54.71	34.00	94.00	7.89
SBP max	182	76.43	41.00	140.00	13.48
DBP min	182	36.24	19.00	64.00	6.98
DBP max	182	55.16	38.00	101.00	11.15
MBP min	182	27.39	12.00	50.00	6.25
MBP max	182	45.27	15.00	86.00	12.09

HR – heart rate, SBP – systolic blood pressure, DBP – diastolic blood pressure, MBP – mean blood pressure

Whitney U test. In all tests conducted, the confidence level $P < 0.05$ was considered statistically significant.

RESULTS

Mean duration of pregnancy in the studied cases was 34.1 ±3 weeks (range: 27–40 weeks); the mean body mass of the studied newborns was 2225 ±743 g (range: 800–4660 g). Success was noticed in 130 cases (71.4%) and failure in 52 (28.6%). There were no significant differences between mean birth weight (2229 ±739 g vs. 2217 ±761 g at $P > 0.9$) as well as between mean gestational age (34.3 ±3.0 vs. 33.6 ±3.0 at $P > 0.2$) in the success and failure groups.

The mean length of I-F therapy in the group with successful I-F intervention was 65 hours. The mean length of I-F therapy in the group with failed intervention was 26 hours. Pharmacological sedation was used in 45 (34.6%) patients from the success group and in 51 (98.1) from the failure group due to anxiety of the newborns.

The measured values of the SpO_2, heart rate, and arterial blood pressure in all analysed cases are shown in Table 1. Min SpO_2 values ranged from 38% to 100% and max from 83% to 100% (Table 1). The min and max registered SpO_2 values were significantly higher (93.3 ±7.28 vs. 85.9 ±14.77 at $P < 0.001$; 99.95 ±0.31 vs. 98.6 ±3.30 at $P < 0.0001$) for the group with successful I-F therapy outcomes than for the group in which the therapy failed (Table 2). In the group with successful I-F therapy outcomes the minimum heart rate was significantly lower (122.5 ±12.37 vs. 135.9 ±14.97 at $P < 0.0001$) than in the group in which the I-F therapy failed. There was no significant difference for the maximum values (Table 2). A higher maximum systolic blood pressure (79.05 ±12.49 vs. 69.78 ±13.73 mm Hg; $P < 0.0001$), maximum diastolic blood pressure (57.03 ±9.31 vs. 50.41 ±13.82 mm Hg; $P < 0.0003$), and maximum mean arterial blood pressure (46.8 ±10.13 vs. 41.39 ±15.46 mm Hg; $P < 0.001$), as well as minimum mean arterial blood pressure (27.88 ±5.71 vs. 26.14 ±7.35 mm Hg; $P < 0.02$) were observed in the group in which the I-F therapy was successful (Table 3).

Pneumothorax was observed in nine (4.94%) newborns, and for that reason non-invasive I-F therapy was discontinued and intubation performed. It was found that the minimum and maximum registered SpO_2 values were significantly higher for the group without pneumothorax than for the group with pneumothorax (Table 4). A faster minimum heart rate (134.4 ±11.97 vs. 125.98 ±14.47 bpm) was observed in the group with pneumothorax, but the difference was of borderline statistical significance ($P > 0.05$). Lower values of maximum systolic pressure (Me – 63 vs. 76 mm Hg; $P > 0.05$), diastolic pressure (Me – 45 vs. 55 mm Hg; $P > 0.05$), and mean pressure (Me – 33 vs. 44 mm Hg; $P > 0.05$) were observed, but the differences were also of borderline statistical significance ($P > 0.05$) (Table 5).

DISCUSSION

Transcutaneously measured haemoglobin oxygen saturation, i.e. SpO_2, heart rate, systolic, diastolic, and mean blood pressure, are commonly used

TABLE 2. Mean, minimum, and maximum values of saturation (SpO_2) and heart rate in accordance with the effectiveness of Infant Flow therapy

Features	Effect	*n*	Mean	Min	Max	SD	*P*
SpO_2 min	Failure	52	85.96	38.00	100.00	14.77	< 0.001
SpO_2 min	Success	130	93.32	42.00	100.00	7.28	
SpO_2 max	Failure	52	98.60	83.00	100.00	3.30	< 0.00001
SpO_2 max	Success	130	99.95	97.00	100.00	0.31	
HR min	Failure	52	135.92	88.00	168.00	14.97	< 0.00001
HR min	Success	130	122.58	78.00	165.00	12.37	
HR max	Failure	52	165.27	133.00	200.00	15.25	> 0.4
HR max	Success	130	168.09	140.00	220.00	15.57	

HR – heart rate

and are the most frequently chosen indicators of the welfare of newborns in intensive care units [12, 15].

These parameters are monitored particularly in newborns treated for various forms of respiratory support. The non-invasive ventilation, which is often used as the first choice of ventilation method, is becoming more and more popular. In the study presented here, the behaviour of the above-mentioned parameters of the condition of the newborn was analysed, depending on the result of the I-F therapy and the occurrence of pneumothorax complications.

Continuous pulse oximetry is possible by using modern oximeters capable of detecting even short-term desaturations, which allows for a quick response in improving the condition of the newborn. The minimum SpO_2 values found in this study ranged from 38% to 100%, and the maximum values ranged from 83% to 100%. This indicates a frequent tolerance of episodes of hyperoxia, which can lead to various adverse effects. In our protocol usually the lowest FiO_2 necessary to maintain SpO_2 at 95% was used. However, a maximum saturation of 100% was observed in individual patients in both groups. The lack of reaction of the doctor on duty to the observed SpO_2 of 100% was due to two reasons. The first was the delayed delivery of such informa-

TABLE 3. Minimum and maximum values of systolic, diastolic, and mean arterial blood pressure in accordance with the effectiveness of Infant Flow therapy

Features	Effect	*n*	Mean	SD	*P*
SBP min	Failure	52	53.96	10.19	> 0.1
SBP min	Success	130	55.00	6.81	
SBP max	Failure	52	69.78	13.73	< 0.0001
SBP max	Success	130	79.05	12.49	
DBP min	Failure	52	36.02	8.79	> 0.4
DBP min	Success	130	36.33	6.17	
DBP max	Failure	52	50.41	13.82	< 0.0003
DBP max	Success	130	57.03	9.31	
MBP min	Failure	52	26.14	7.35	< 0.02
MBP min	Success	130	27.88	5.71	
MBP max	Failure	52	41.39	15.46	< 0.001
MBP max	Success	130	46.80	10.13	

SBP – systolic blood pressure, DBP – diastolic blood pressure, MBP – mean blood pressure

TABLE 4. Median, minimum, and maximum values of saturation ($Sp0_2$) and heart rate (HR) in accordance with occurrence of pneumothorax

Features	Pneumothorax	*n*	Median	Min	Max	*P*
$Sp0_2$ min	No	173	95.0	42.0	100.0	< 0.0034
$Sp0_2$ min	Yes	9	82.0	38.0	100.0	
$Sp0_2$ max	No	173	100.0	90.0	100.0	< 0.004
$Sp0_2$ max	Yes	9	100.0	83.0	100.0	
HR min	No	173	125.00	78.00	168.00	> 0.0629
HR min	Yes	9	131.00	117.00	154.00	
HR max	No	173	166.00	133.00	220.00	> 0.4691
HR max	Yes	9	160.00	147.00	182.00	

TABLE 5. Minimum and maximum values of systolic, diastolic, and mean arterial blood pressure in accordance with occurrence of pneumothorax

Features	Pneumothorax	*n*	Median	Min	Max	*P*
SBP min	No	173	54.00	34.00	94.00	> 0.34
SBP min	Yes	9	58.00	38.00	66.00	
SBP max	No	173	76.00	41.00	140.00	> 0.054
SBP max	Yes	9	63.00	55.00	97.00	
DBP min	No	173	35.00	19.00	64.00	> 0.07
DBP min	Yes	9	40.00	24.00	59.00	
DBP max	No	173	55.00	19.00	101.00	> 0.059
DBP max	Yes	9	45.00	41.00	91.00	
MBP min	No	173	27.00	12.00	50.00	> 0.80
MBP min	Yes	9	28.00	17.00	47.00	
MBP max	No	173	44.00	15.00	81.00	> 0.0503
MBP max	Yes	9	33.00	27.00	86.00	

SBP – systolic blood pressure, DBP – diastolic blood pressure, MBP – mean blood pressure tion from the nursing staff. The second was the lack of a decision by some doctors to lower FiO_2 for fear of deterioration of the newborn. The analysis performed by us made it possible to discover this fact and to revise the conduct of medical staff in this matter.

In the literature on the use of non-invasive breathing support in preterm newborns, it is recommended that maximum SpO_2 values should not exceed 95% [16]. It should be emphasised that in the course of this study, significantly higher minimum SpO_2 values were observed in the successful I-F therapy group than in the failed group. In the latter group, SpO_2 values averaged 85.9%, which confirms the observations made by other authors proving that SpO_2 < 86% is a determinant of failure of non-invasive respiratory support. In the group with successful I-F therapy and with a mean gestational age of 34.3 weeks, the minimum SpO_2 value in this study was 93.3% (lower than the recommended 95% safe border value for newborns earlier than 32 weeks of gestation).

Mascoll-Robertson *et al.*, in a study conducted in a group of 35 newborns qualified according to the author's research protocol, covering a gestational age between 24 and 32 weeks, showed that newborns with SpO_2 values below 86% for more than 15% of the day required intubation and mechanical ventilation due to failure of the non-invasive ventilation [17]. In the group with this type of ventilation failure, they recorded SpO_2 values < 86% in 11% of the newborns, while in the group with successful therapy it was seen in only 3% ($P < 0.02$). In the successful treatment group, they most often recorded SpO_2 values > 95%, and these neonates even had reduced FiO_2 after disconnection from respiratory support, compared to pre-disconnection [17].

Interesting observations were published by Lim *et al.* in a group of premature newborns treated with the CPAP method [18]. The episodes of prolonged hyperoxia they recorded ≥ 96% covered 21% of the day, among them 7.8% of the day recorded SpO_2 values were ≥ 98%. This could be explained by an inadequate number of nurses. According to the nurses, optimal care for newborns treated using the CPAP method is one nurse per newborn. This allows for quick reduction the FiO_2 concentration to the child's current situation. Hypoxia episodes < 80% with bradycardia were observed no more than once a day in 16% of the newborns. It is very interesting that the less experienced nurses reacted faster to episodes of hypoxia and hyperoxia, while the more experienced staff waited for spontaneous regulation of saturation by the child, or changed parameters other than FiO_2 concentration, e.g. CPAP pressure [18]. Hensey *et al.* showed that the use of oxygen supplementation at low gas flow reduces the incidence of desaturation episodes < 80% and < 85%, and shortens the length of treatment in premature babies [19]. This did not significantly affect the incidence of bradycardia < 100/min [19]. Sobczyk reports that increasing CPAP levels from 4 to 6 cm H_2O resulted in a marked increase in oxygen saturation of haemoglobin measured with a pulse oximeter in newborns with SpO_2 < 90% [20]. SpO_2 values recorded in the newborns depended not only on the state of respiratory efficiency and age of the newborn, but also on a number of other factors. Phillipos *et al.* noted that delaying umbilical cord closure contributed to a faster increase in SpO_2 levels and heart rate in preterm newborns requiring CPAP in the delivery room [21]. Newborns born at the same gestational age (up to 32 weeks of gestation) without breathing problems reached the required SpO_2 and heart rate limits earlier [21]. In their research, Brunherotti *et al.* assessed the dependence of respiratory rate, heart rate, and SpO_2 values depending on one of four body positions in newborns treated with CPAP method, born between at 26 and 33 weeks of gestation with an average body weight of 1352 g [22]. They found no correlation between the respiratory rate and heart rate and the child's upright position, while in the left- or right-side position they recorded significantly lower SpO_2 values than in the position on the child's back or stomach [22]. The original pilot study was conducted by Sweet *et al.* in a group of 16 newborns who were born with at average gestational age of 29.8 weeks of pregnancy [23]. They assessed the behaviour of heart function, number of breaths, and SpO_2 during the suction procedure of newborns treated with CPAP. These authors emphasise that the suction procedure is painful and is associated with the possibility of bradycardia, fluctuations in blood pressure, hypoxaemia, and arrhythmia. However, they did not notice significant changes in the number of breaths and heart function, while SpO_2 decreased significantly after the neonatal suction procedure, and recovery to the value preceding the suction took place after about 10 minutes [23]. It is interesting to note that the more mature the newborn is, the longer the SpO_2 recovery time is necessary to reach to baseline SpO_2 values noticed before the suction procedures ($P > 0.05$). Each one-week increase in gestational age was associated with 1.7 minutes additional time to obtain primary values [23].

In the results presented in this study, we did not assess the monitored parameters immediately after neonatal suction, so it did not have a significant impact on the recorded values of parameters of the newborn.

Assessment of the condition of newborns treated with non-invasive respiratory support is mainly focused on improving the respiratory capacity of newborns. Very few reports describe how this form of therapy affects the cardiovascular system of treated newborns. This can be assessed by monitoring heart function and blood pressure. Maffei *et al.* in a review of non-invasive ventilation among the effects of CPAP on the cardiovascular system mention the possibility of hypotension [24]. It seems possible that decreased intrathoracic pressure with CPAP use will alter pulmonary, systemic, and transductal blood flow and may contribute to a decrease in blood pressure [25].

The preferred method of measuring blood pressure in critically ill newborns is the direct method from access via the umbilical or radial artery [26]. Blood pressure measured directly by the arterial line allows continuous monitoring of this parameter; however, establishing and maintaining an arterial line may be difficult in premature newborns. It is also associated with an increased risk of thrombosis and infection [27]. The arterial line established through access from the umbilical artery should not be maintained for more than five days [28]. Many authors describe the use of an oscillometric non-invasive method of measuring blood pressure in premature babies using a suitable cuff on the right or left shoulder [15, 25, 29]. This method of measurement was also used in this study in all assessed newborns during non-invasive ventilation using the I-F method. Both compliance and differences in recorded blood pressure values measured by both methods in premature babies were described; the largest differences were observed in the range of diastolic pressure [30]. Less than 30 mm Hg mean arterial pressure can lead to unnecessary intravenous fluid and inotropic supply in a situation of low blood pressure [26]. Shimokaze *et al.* conducted a study comparing blood pressure values obtained by indirect oscillometric and direct methods in 74 newborns born from 24 to 42 weeks (mean 31.2 weeks) and with body weight on average 1453 g [30]. They obtained values of coefficients systolic, diastolic, and mean arterial pressure of 0.87, 0.82, and 0.84, respectively ($P < 0.001$). These researchers also found that the mean systolic blood pressure values did not significantly differ depending on the measurement method used, while the diastolic blood pressure values assessed by the indirect method were underestimated, i.e. significantly lower than those found in the direct method ($P < 0.001$). Gestational age, body weight, and cardiac function did not significantly correlate with the blood pressure values of the neonates examined by them [30].

The literature reports most often the effect of mean blood pressure on treatment outcomes qualified as success or failure, with an emphasis on hypotensive episodes requiring pharmacological correction [25, 31–33]. It has been described that newborns remaining in the Intensive Care Unit due to respiratory failure often show a tendency of lower blood pressure during the first 24 hours of life [25]. It should be emphasised that there is no uniform definition of hypotension in premature newborns. Lakkundi defined the problem of hypotension in prematures with respiratory failure in the first 72 hours of life, with mean arterial pressure lower than the gestational age of the newborn [25]. Treatment of hypotension was initiated when clinical signs of poor perfusion occurred. They also described that the failure of INtubate, SURfactant, Extubate (INSURE) treatment was associated with a previous episode of low mean arterial pressure, which was observed in 16% of the 116 assessed neonates born at gestational age on average 26 weeks and with an average body weight of 940 g [25].

Treatment of hypotension is based on the belief that low blood pressure negatively affects the final outcome of the newborn. Lakkundii *et al.* believe that non-invasive ventilation reduces the incidence of hypotension requiring treatment [25]. Probably lower incidence of continuous sedation/analgesia when using non-invasive ventilation, compared to invasive ventilation, reduces the incidence of low blood pressure episodes [25].

Korraa *et al.* during the kangaroo mother care of premature babies described a slowdown in heart function and an increase in blood pressure, which are associated with a decrease in the severity of stress in premature babies requiring oxygen therapy [15]. They examined children born on average at 32 weeks of gestation and with an average body weight of 2080 g. Sobczyk noticed no effect of CPAP on heart rate and average arterial blood pressure in a group of 40 newborns with gestational age of 32.5 weeks of pregnancy and with body weight 1979 g [20]. Abdel-Hady *et al.* reported that CPAP + 5.0 cm H_2O had no effect on the left ventricular shortening end fraction, heart rate, and mean blood pressure [34]. Levett also found no significant effect of CPAP on heart rate and average blood pressure [35]. Yu and Rolfe stated that the use of CPAP in children with respiratory distress syndrome must be cautious and in combination with monitoring of respiratory and cardiovascular function because exceeding the proper airway pressure can lead to respiratory and circulatory system disorders [36].

In the observation conducted in this study, the group with pneumothorax had significantly lower minimum and maximum saturation values compared to the group without pneumothorax. Lower maximum systolic and mean pressure were also found but were not significant ($P > 0.05$). In most babies from the failure group (98.1%) indications for pharmacological sedation were observed. Anxiety was an undesirable phenomenon due to the possibility of pneumothorax. On the one hand, the anxiety of the newborn baby during the I-F method could indicate inadequately selected ventilation parameters for the child's condition; on the other, it could be due to the discomfort caused by mounting the nasal prongs on the child's face.

There are some limitations of our study. It was a single-centre retrospective observation in a group of more mature neonates. It is worth performing a prospective multicentre study in a group of very-low-birthweight neonates born before 32 weeks of gestation.

It should be emphasised that during the years 2009–2014 we did not have a rigid protocol for treating newborns using the I-F method. The data obtained on the basis of our analysis showed discrepancies in the field of FiO_2 used, interventions undertaken in the case of desaturation, and acceptable desaturation time. It allows us to prepare the precise protocol of the treatment with using non-invasive method of the respiratory support. We expect this to improve our results in the use of non-invasive ventilation.

CONCLUSIONS

1. In newborns suffering from respiratory failure and treated with I-F, higher SpO_2 values, lower heart rate, and higher arterial blood pressure coincide with success of the I-F therapy.
2. In newborns diagnosed with pneumothorax, lower saturation, lower arterial blood pressure, and higher heart rate were observed during treatment with the I-F method, at the stage before the occurrence of pneumothorax.

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