Pediatrics & Therapeutics
ISSN: 2161-0665

Battisti et al., Pediatr Therapeut 2012, 2:2
DOI: 10.4172/2161-0665.1000114

Research Article Open Access

Lung Compliance and Airways Resistance in Healthy Neonates

Oreste Battisti[1]*, Jean-Marie Bertrand[2], Hatem Rouatbi[3] and Gustavo Escandar[3]

[1]Academic Professor of Pediatrics and Neonatal Medicine, University of Liège, Belgium, Department of Pediatrics, University of Liège and Honorary Consultant, Neonatal Intensive Care Unit, Clinique Saint-Vincent de Paul, Liège, Belgium
[2]Neonatal Intensive Care Unit, Clinique Saint-Vincent de Paul, Liège, Belgium
[3]Residents in pediatrics, Department of Pediatrics, University of Liège, Belgium

Abstract

Objectives: This study aimed to determine the values and their evolution of Crs and Rrs during the first 3 weeks of life.

Subjects and methods: We carried out a longitudinal study of static lung compliance (Crs) and airways resistance (Rrs) in apparent healthy preterm and term neonates (n=32), and further in a group of preterm babies with a respiratory distress syndrome (n=10). Lung function testing was performed at day 1, 3, 7, 14, 21. Additive sedation, when necessary, was given orally (chloral hydrate 50 mg/kg). The instrumentation was the 2605 Infant Hugger prototype.

Results:

The healthy or control population: The female neonates had significantly higher values of Crs, and this was present already at birth and remained so after birth. There was a significant increase (20%) of static lung compliance after birth and that increase remained in a plateau state. The changes in Rrs showed no statistically differences after birth within both groups, but Rrs after birth was significantly lower when more mature babies were compared with more premature neonates. It was also interesting to note that Rrs increased after birth in more premature babies without reaching a statistical significance however.

The neonates with RDS: In comparison to the control population, the static lung compliance had an important reduction of Crs : nearly 4 fold decrease in the begin of disease, and this remained a 2 fold decrease till 14 days. The sick neonates, again in comparison to the control group, had an important increase of Rrs: about 3 fold increase in the begin of disease, and 50 % increase at 14 days.

Conclusion: The Crs and Rrs observed in healthy neonates should be inserted in software of instruments for respiratory support (also nasal CPAP) in order to improve the strategy and decision during the acute phase.

Keywords: Lung function; Compliance; Airways resistance; Prematurity; Respiratory distress

Introduction

Sick newborn babies have frequently respiratory difficulties and hence they may require a type of ventilator support [1-6]. The fetal lung maturation by steroids given in the pregnancies carrying the risk of prematurity, together with a better control of the perinatal infection and a better and more appropriate nutrition are the major explaining factors for the decrease in the frequency and severity of respiratory distress or RDS in newborn babies [2]. The most frequent mode of neonatal respiratory support at the present time is the nasal continuous positive airway pressure or nCPAP. The high frequency oscillatory ventilation (HFOV), the conventional ventilation and the administration of surfactant tube are still used. Actually, the neonates born lately premature (> 34 weeks gestational age), and this is probably due to a combination of perinatal infection and a less well fetal preparation, may present a severe respiratory malfunction in the acute phase. The chronic lung disease or bronchopulmonary dysplasia (BPD) has also declined in its frequency and severity [3,6,7].

Several studies concerning lung function in preterm and term infants have already been reported concerning the neonatal period and the follow up lifetime [8-29]. We are aware that the numeric findings of Crs and Rrs values in this study are not new. To our knowledge, this type of study where these parameters are precisely analyzed are scarce in the literature. This work is a part of several prospective research projects started in 1990 and still continuing [11-13,17-19,30-32]. The target of these studies are: 1. To define the strategy and the effects of HFOV or high frequency ventilatory oscillation; 2. To define the parameters of cerebral blood flow auto regulation; 2. To analyze the effects of drugs, general anesthesia and surfactant therapy on cerebral circulation. In the present study, the project was to follow the values and their changes of lung compliance (CRs) and airways resistance (Rrs) during the first weeks of life in apparently normal premature newborns in order to apply these parameters of lung function during the acute phase of babies with RDS supported by n CPAP.

Subjects and Methods

Subjects

This study comprised 32 neonates as the **control group** (Table 1). The apparent healthy state of these babies in the neonatal period has been confirmed in the long term follow-up (final age of 9 years) by a consequent normal growth, a normal development, an absence

***Corresponding author:** Oreste Battisti, Academic Professor of Pediatrics and Neonatal Medicine, University of Liège, Belgium, Department of Pediatrics, University of Liège and Honorary Consultant, Neonatal Intensive Care Unit, Clinique Saint-Vincent de Paul , Liège, Belgium, E-mail: oreste.battisti@ulg.ac.be

Received January 12, 2012; **Accepted** February 05, 2012; **Published** February 06, 2012

Citation: Battisti O, Bertrand JM, Rouatbi H, Escandar G (2012) Lung Compliance and Airways Resistance in Healthy Neonates. Pediatr Therapeut 2:114. doi:10.4172/2161-0665.1000114

of airways hyper reactivity. The premature neonates were those born before 37 weeks. They did not present any respiratory difficulties, were not infected, had none malformation and had a normal fetal growth. This control group was further divided in two subgroups owing to the attended surfactant synthesis and the previously mentioned fragility of late prematurity: those born before 34 weeks, and those born after 33 weeks 6 days. Even if the samples of both populations (control and sick neonates) may look small, they were sufficient to meet the Student's test statistical criteria, together with the number of measures done sufficient [33,34] (Tables 1 and 2).

Methods

Lung function testing was performed at day 1, 3, 7, 14, 21. The sedation, when necessary, was given orally (chloral hydrate 50 mg/kg). The instrumentation was the 2605 Infant Hugger prototype, a pneumotach instrument with a complete flow measurement system including pressure transducers and electronics for Flow Sensor input, an auxiliary pressure input, and analog outputs. It can calculate flow rates and provide correction for gas density, viscosity, temperature, barometric pressure, and airway pressure. It automatically detects start and end of breath and calculates the following ventilatory parameters: tidal breathing, I and E volumes, respiratory rate, I and E time, static and dynamic compliance, resistance, terminal compliance, PEP, PIP, MAP, FRC. It can be used through a facial mask or through the endotracheal tube. On primary intention, owing to their importance in lung mechanics, we recorded the lung static compliance (Crs) expressed in ml/cm H2O/sec, and the static airways resistance (Rrs) expressed in cm H20/ml/sec

Results

Analysis of the static lung compliance in the control population

When we compared the results concerning Crs changes after birth between males and females in the control group, we see that female neonates had significantly higher values of Crs. And this was present already at birth and remained so after birth (Tables 3, 4 and 5).

	Gestational age Median (ranges)	Birthweight Median (ranges)	Number of measures per infant Median (ranges)
Preterm (n=23)	32 (25-36)	1935 (1180 – 2685)	5 (1-10)
Term (n=9)	38 (37-42)	2985 (1820 – 4150)	2 (1-5)

The ***group of sick preterm babies*** (Table 2) contained 10 patients who had a RDS due to an hyaline membrane disease.

Table 1: The Control group (n = 32, and the total number of lung evaluation = 195).

	Gestational age Median (ranges)	Birthweight Median (ranges)	Number of measures per infant Median (ranges)
Preterm (n=10)	32 (25-34.5)	1700 (640-2300)	4 (1-9)

Table 2: The Group of sick preterm neonates (n=10, total number of evaluation 58).

Day	Result of Crs mean ± SD
1	1.28 ± 0.40
3	1.50 ± 0.25
7	1.63 ± 0.46
14	1.53 ± 0.55

Table 3: Lung function in the control group born before 34 weeks: compliance or Crs (number of measures = 120).

Day	Results of Crs mean ± SD
1	1.41 ± 0.37
3	1.64 ± 0.33
7	1.68 ± 0.39
14	1.68 ± 0.26

Table 4: Lung function in the control group born after 33 weeks 6 days: compliance (number of measures = 75).

days	males	females
1	1.24 ± 0.26	1.45 ± 0.42
3	1.44 ± 0.27	1.67 ± 0.43
7	1.54 ± 0.40	1.75 ± 0.41
14	1.51 ± 0.37	1.71 ± 0.50

Table 5: Lung function in the control group: Crs and sex of babies (number of measures is 100 in males and 95 in females).

Day	Results of Rrs mean ± SD
1	0.054 ± 0.17
3	0.069 ± 0.018
7	0.057 ± 0.011
14	0.064 ± 0.010

Table 6: Lung function in the control group before 34 weeks: the static resistance or Rrs (number of measures = 128).

Day	Results of Rrs mean ± SD
1	0.046 ± 0.017
3	0.052 ± 0.19
7	0.049 ± 0.12
14	0.049 ± 0.011

Table 7: Lung function in the control group after 33 weeks 6 days: the static resistance (number of measures = 32).

When all the babies were gathered, whatever the gestational age or sex at birth, we obtained the following values (mean ± SD):

- At day 1: 1.37 ± 0.37 ml/cm H_2O/sec
- At day 3: 1.60 ± 0.40
- At day 7: 1.67 ± 0.41
- At day 14: 1.62 ± 0.44
- At day 21: 156 ± 0.42

There was a significant increase of Crs of observed after birth and it remained relatively stable afterwards. It is interesting to note, however, that the greatest increase was always observed at day 7. If we take into consideration the gestational age and the sex at birth, other significant differences appeared: 1. a statistically significant increase of Crs after the day 1 within both subgroups and a significant difference in the absolute increase of Crs between both subgroups.

In both sexes, there was a significant increase (20 %) of static lung compliance after birth, and that increase remained stable in a plateau. The greatest increase was always observed at day 7.

Analysis of the static airways resistance in the control population

When all the babies were gathered, whatever the gestational age or sex at birth, we obtained the following values (mean ± SD) (Tables 6 and 7):

- At day 1: 0.048 ± 0.17

- At day 3: 0.057 ± 0.020

- At day 7: 0.052 ± 0.012

- At day 14: 0.057 ± 0.013

- At day 21: 0.060 ± 0.015

The global increase of Rrs over the days was 25 %. This increase in Rrs, even if interesting to be observed after birth, was however not statistically significant.

When the gestational age at birth was considered, significant differences appeared.

The changes in Rrs showed no statistically differences after birth within both groups, but Rrs after birth was significantly lower when more mature babies were compared with more premature neonates. It was also interesting to note that the progressive increase in Rrs after birth observed in more premature babies could not reach a statistical significance. The end of the first postnatal week of life evidenced the smallest Rrs.

Analysis of the static lung compliance and airways resistance in the sick population

Lung compliance: The sick neonates, in comparison to the control population, had an important reduction of Crs: nearly 4 fold decrease in the begin of disease, and this remained a 2 fold decrease till 14 days (Table 8).

Airways resistance: The sick neonates, again in comparison to the control group, had an important increase of Rrs: about 3 fold increase in the begin of disease, and 50 % increase at 14 days.

In our population of sick neonates, both lung tissue for gas exchange (alveolar tree) and airways conductance were concerned on an important level. The observed values of Crs and Rrs reflect the fact that the the alveolar tree was more affected than the conductive part, and mainly in the acute phase of disease. On a level of lung mechanics' terms, this is corresponding to state associating an obstructing and a restricting state.

Discussion

We consider the present work as an opportunity for adding a consideration on physiology of lung mechanics in early life among other studies. We may say that the observed changes at birth and during the postnatal days reflect the adaptation of lung function (see introduction). The observed increase in Crs is probably due to a combination of several factors: the progressive disappearance of the interstitial fluids, the intervention of endogenous surfactant effect on alveolar surface, and the adaptation of airways resistance on the outflow of air. These combined events could explain the observed highest (for Crs) and lowest (for Rrs) values at the end of the first week of life. Again, these same events, not really found in the population of sick neonates with RDS, could explain the fact that the physiological adaptation could not be encountered in these infants. With the improvement in survival rate of very low birth weight infants (birth weight less than 1500 g), research efforts have been devoted to developing new ventilation strategies to reduce lung damage from positive pressure ventilation, to maintain an appropriate circulation and to preserve the brain. The principal benefits of ventilation are improved gas exchange, decrease work of breathing, and ventilation for patients with apnea or respiratory depression. The lung mechanics in neonates has been well studied over the years. The mode of neonatal ventilator support has changed over the years even if more prematurely newborn babies are taken in charge in neonatal intensive care units (see above). The antenatal lung maturation by steroids and the postnatal use of surfactant, together with other measures of treatments explain this evolution. Nasal CPAP is now the most frequent mode of ventilator support. The new ventilators deserve more and more a screen showing continuously the lung functions loops. This increases the possibility to follow the optimality of ventilation and also to provide parameters (flow-volume loop, pressure-volume loop, Crs and Rrs) which are important for the decision during sickness, and also for the prognosis and outcome. The possibility to setup alarms for these parameters within the ventilator, as it is already feasible for other paramters outside the ventilator (heart and respiratory rates, saturation, blood pressure) would be beneficial when mechanical ventilation is needed. As nCPAP is actually the most frequent mode of ventilator support in neonates, an instrumentation of lung functions tests using here the jacket mode for plethysmography could bring to the clinician interesting points. This allows further to follow the effects of surfactant therapy, fluid therapy, ductus arteriosus shunting therapy not only on the lung function, but also on the hemodynamics of the brain, and the use of nitrogen instead of helium allows the analysis of lung diffusion, and that would further provide a way to follow the lung state in these babies, not solely in the acute phase but also in the recovering of a BPD phase. In our opinion, an instrument like Exhalyzer D for lung function assessment in all aspects seems suitable for this kind of study. All these points represent several reasons for a neonatologist but also for nurses working in neonatal intensive care units to have a good knowledge of the significance of the different loops visible on the screen of ventilator support, in order to better assess the state of lung function in the sick neonate.

Days	Crs ml/cmH20/kg Mean ± SD	Rrs cmH20/ml/sec Mean ± SD
1	0.57 ± 0.00285	0.156 ± 0.0005
3	0.40 ± 0.002	0.129 ± 0.0004
7	0.65 ± 0.003	0.157 ± 0.0005
14	0.73 ± 0.004	0.472 ± 0.0001

Table 8: Lung function in the sick population (number of measures= 59).

References

1. Bush A (2006) Update in pediatrics 2005. Am J Respir Crit Care Med 173: 585-592.
2. Colin AA, McEvoy C, Castile RG (2010) Respiratory morbidity and lung function in preterm infants of 32 to 36 weeks' gestational age. Pediatrics 126: 115-128.
3. Jobe AH (2011) Lung Development and maturation. In: Neonatal-Perinatal Medicine, 2, 9th, Martin RJ, Fanaroff AA, Walsh MC (Eds), Elsevier Mosby, St Louis p.1075.
4. Greenough A, Dimitriou G, Prendergast M, Milner AD (2008) Synchronized mechanical ventilation for respiratory support in newborn infants. Cochrane Database Syst Rev: CD000456.
5. De Paoli AG, Davis PG, Lemyre B (2003) Nasal continuous positive airway pressure versus nasal intermittent positive pressure ventilation for preterm neonates: a systematic review and meta-analysis. Acta Paediatr 92: 70-75.
6. Jacob SV, Coates AL, Lands LC, MacNeish CF, Riley SP, et al. (1998) Long-term pulmonary sequelae of severe bronchopulmonary dysplasia. J Pediatr 133: 193-200.
7. Jobe AJ (1999) The new BPD: an arrest of lung development. Pediatr Res 46: 641-643.

8. Gerhardt T, Hehre D, Feller R, Reifenberg L, Bancalari E (1987) Serial determination of pulmonary function in infants with chronic lung disease. J Pediatr 110: 448-456.

9. Hakulinen AL, Heinonen K, Länsimies E, Kiekara O (1990) Pulmonary function and respiratory morbidity in school-age children born prematurely and ventilated for neonatal respiratory insufficiency. Pediatr Pulmonol 8: 226-232.

10. Edberg KE, Sandberg K, Silberberg A, Ekström-Jodal B, Hjalmarson O (1991) Lung volume, gas mixing, and mechanics of breathing in mechanically ventilated very low birth weight infants with idiopathic respiratory distress syndrome. Pediatr Res 30: 496-500.

11. Lecart C, Battisti O, Guissard F, François A, Langhendries, J, et al. (1992) Pulmonary mechanics in full term and prematurely born neonates during the first two weeks of life. Paper presented at - Vienna, Austria.

12. Lecart C, Battisti O, Guissard F, François A, Langhendries J, et al. (1992) Respiratory system compliance in prematurely born neonates with idiopathic respiratory distress syndrome : prognostic value. Paper presented at-Vienna, Austria.

13. Lecart C, Battisti O, Guissard F, François A, Langhendries J, et al. (1993) Early use of HFOW in the management of hyaline membrane disease in prematurely born neonates. Paper presented at Snowbird high frequency conference, Salt Lake city.

14. Cleary JP, Bernstein G, Mannino FL, Heldt GP (1995) Improved oxygenation during synchronized intermittent mandatory ventilation in neonates with respiratory distress syndrome: a randomized, crossover study. J Pediatr 126: 407-411.

15. Hakulinen AL, Järvenpää AL, Turpeinen M, Sovijärvi A (1996) Diffusing capacity of the lung in school-aged children born very preterm, with and without bronchopulmonary dysplasia. Pediatr Pulmonol 21: 353-360.

16. Iles R, Edmunds AT (1997) Assessment of pulmonary function in resolving chronic lung disease of prematurity. Arch Dis Child Fetal Neonatal Ed 76: F113-117.

17. Battisti O (1997) Respiratory profile in RDS infants assisted by primary HFOV using an early lung volume optimization strategy and a selective surfactant therapy. Paper presented at international symposium on HFVO, Ovifat, Belgique.

18. Kalenga M, Battisti O, François A, Langhendries J, Gerstmann D, et al. (1997) Respiratory profile in RDS infants assisted by primary HFOV. Paper presented at first European conference on high frequency ventilation, Ovifat, Belgium.

19. Kalenga M, Battisti O, François A, Langhendries J, Bertrand J (1998) Early HFOV parameters and respiratory tcome in RDS newborns less than 32 weeks of gestational age. Paper presented at international symposium on HFVO, Ovifat, Belgique.

20. de Winter JP, Merth IT, Brand R, Quanjer PH (2000) Functional residual capacity and static compliance during the first year in preterm infants treated with surfactant. Am J Perinatol 17: 377-384.

21. Hjalmarson O, Sandberg K (2002) Abnormal lung function in healthy preterm infants. Am J Respir Crit Care Med 165: 83-87.

22. Hülskamp G, Hoo AF, Ljungberg H, Lum S, Pillow JJ, et al. (2003) Progressive decline in plethysmographic lung volumes in infants: physiology or technology? Am J Respir Crit Care Med 168: 1003-1009.

23. Robin B, Kim YJ, Huth J, Klocksieben J, Torres M, et al. (2004) Pulmonary function in bronchopulmonary dysplasia. Pediatr Pulmonol 37: 236-242.

24. Friedrich L, Stein RT, Pitrez PM, Corso AL, Jones MH (2006) Reduced lung function in healthy preterm infants in the first months of life. Am J Respir Crit Care Med 173: 442-447.

25. Baldwin DN, Pillow JJ, Stocks J, Frey U (2006) Lung-function tests in neonates and infants with chronic lung disease: tidal breathing and respiratory control. Pediatr Pulmonol 41: 391-419.

26. Gappa M, Pillow JJ, Allen J, Mayer O, Stocks J (2006) Lung function tests in neonates and infants with chronic lung disease: lung and chest-wall mechanics. Pediatr Pulmonol 41: 291-317.

27. Hülskamp G, Pillow JJ, Dinger J, Stocks J (2006) Lung function tests in neonates and infants with chronic lung disease of infancy: functional residual capacity. Pediatr Pulmonol 41: 1-22.

28. Baraldi E, Filippone M (2007) Chronic lung disease after premature birth. N Engl J Med 357: 1946-1955.

29. Fakhoury KF, Sellers C, Smith EO, Rama JA, Fan LL (2010) Serial measurements of lung function in a cohort of young children with bronchopulmonary dysplasia. Pediatrics 125: e1441-1447.

30. Battisti O (1998) High frequency oscillatory ventilation in RDS. Pediatr Res

31. Gerstmann DR, Minton SD, Stoddard RA, Meredith KS, Monaco F, et al. (1996) The Provo multicenter early high-frequency oscillatory ventilation trial: improved pulmonary and clinical outcome in respiratory distress syndrome. Pediatrics 98: 1044-1057.

32. Battisti O, Detry J, Louis J, François A, Chedid F, et al. (1994) Cerebral blood flow velocities during natural bovine surfactant therapy in very preterm babies. Circulation et Métabolisme du Cerveau 11: 33-48.

33. Laplnache A, Com-Nougué C, Flamant R (1987) Méthodes statistiques appliqués à la recherche clinique. Médecine-Sciences Flammarion (Paris), 168p.

34. Schwartz D (1989) Méthodes statistiques à l'usage des médecins et des biologists. Flammarion Médeine-Sciences (Paris), 306p.

35. Nitta K, Kobayashi T (1994) Impairment of surfactant activity and ventilation by proteins in lung edema fluid. Respir Physiol 95: 43-51.

36. Khalaf MN, Brodsky N, Hurley J, Bhandari V (2001) A prospective randomized, controlled trial comparing synchronized nasal intermittent positive pressure ventilation versus nasal continuous positive airway pressure as modes of extubation. Pediatrics 108: 13-17.

37. Latzin P, Roth S, Thamrin C, Hutten GJ, Pramana I, et al. (2009) Lung volume, breathing pattern and ventilation inhomogeneity in preterm and term infants. PLoS One 4: e4635.

38. Balinotti JE, Chakr VC, Tiller C, Kimmel R, Coates C, et al. (2010) Growth of lung parenchyma in infants and toddlers with chronic lung disease of infancy. Am J Respir Crit Care Med 181: 1093-1097.

39. Kalenga M, Battisti O, François A, Langhendries JP, Gerstmann DR, et al. (1998) High-frequency oscillatory ventilation in neonatal RDS: initial volume optimization and respiratory mechanics. J Appl Physiol 84: 1174-1177.

40. Battisti O (1998) Early surfactant changes after surfactant therapy in premature infants assisted by HFOV. Pediatr Res 2: 287.