Pediatrik Cerrahi Dergisi 3: 140-142, 1989

Neonatal intensive care: What is the impact of chest wall/lung mechanics for respiratory support in the sick newborn baby?

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Perinatal respiratory adaptation

In the newborn baby at birth a dramatic adaptational change in circulation and respiration is taking place. The aim of respiration is to satisfy the basal metabolic maintenance rate of O_2 and CO_2. Before birth this exchange is via the placenta and the mother but after birth mainly through the lung alveoli of the newborn baby.

The prerequisites for alveolar gas exchange after birth is related to the following factors:

1. Morphological development of lung capillaries and airways.
2. Fetal lung maturation of hormones and surfac tant.
3. Intrauterine fetal respiration activity.
4. Pulmonary adaptational changes at birth, i.e. labour, mode of delivery, cathecholamine drive and lung fluid absorption.
5. Reflex activity in the lungs and neurosensory state.
6. Rib cage development, i.e. chest wall stability and intercostal/diaphragma muscle development and activity.
7. Cardiopulmonary circulatory adaptation mainly related to ductal closure.

Over the first 24 hours after birth there is a dramatic change in lung mechanics with increase in both compliance and functional residucal capacity along with fall in lung resistance in the normal newborn infant (Fig. 1) [1].

Postnatal regulation of respiration

PULMONARY MECHANICS IN NEWBORN RESPIRATORY CONTROL

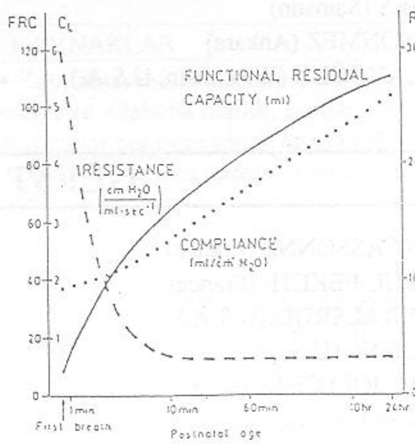

Fig. I. Lung mechanics in normal newborn infants during the first 24 hours of life showing fall in resistance and increase in compliance and functional residual capacity (1).

In morphometric measurements of lung alveoler development it has been shown that the lung volume increases four-fold between the 29th and 40th week of gestation and is doubled from fullterm until 4 month of postnatal age [2]. Although the lung morphology is not fully developed in the fullterm infant the baby still has several strategies to support respiration and maintain blood gas homeostasis. Immediately after birth the threshold levels for the chemo receptors for pO_2 and pCO_2 are similar to the fetal level. Still adaptation to extrauterine demands will occur within a few days. Fetal respiratory movements in utero will occur from the 11th week of gestation with increasing activity at the end of gestation.

Thus the respiratory muscles have been "in training" in utero and will usually function effectively although a limited capacity compared to adults has been in shown in newborn infants. The soft chest wall of the newborn baby is functionally stabilized through tonic activity in the intercostal muscles. Finanlly, functional residual capacity of the lungs can be supported in the newborn infants through a prolonged expiration by postinspiratory activity in the diaphragmatic muscle in addition to the capacity of the larynx to break expiration through contraction, i.e. the phenomenon of grunting or so-called auto-PEEP (positive end expiratory pressure) [3].

Respiratory support nechanisms in immature or sick infants

In immature preterm infants or sick newborn infants with lung disease or congenital malformations affecting lung function the capacity for compensatory increase of ventilation is limited. The ventilatory increase with increasing pCO_2 is lower especially during the first day of life but increases during the first three weeks of life. The ventilatory response will be an increase of respiratory rate and a limited increase in tidal volume. However, in sick newborn infants and preterm infants the lower muscle capacity especially in the diaphragm makes the mewborn baby highly susceptible to muscle fatigue and ventilatory insufficiency. As a counteractive measurement the baby will recruit also abdominal musculature and through the larynx contraction with grunting the baby will obtain a certain relief on the diaphragmatic muscle work and also through auto-PEEP recruit new alveoli opening [4]. These mechanisms will increase functional residual capacity and improve the gas exchange through an increased lung alveolar area. These mecanisms will increase functional residual capacity and improve the gas exchange through an increased lung alveolar area. These are the basic mechanisms through which the newborn infant can maintain gas exchange even during diseases like pneumonia or congenital malformations affecting the lungs. Application of continuous positive airways pressure is thus an important technique for respiratory support in neonatal intensive care today [5].

After the 32nd week of gestation the above mentioned defense mechanisms are usually well developed in the newborn infant. However, this capacity varies considerably between individual babies before the 32nd week and especially in very immature babies born between 24 and 29 weeks of gestation. This is a main factor in the condition seen in preterm infants with apnoea of immaturity also called chronic pulmonary insufficiency of prematurity, which develops during the first days of life and persists for one, two or three weeks [6]. This condition in addition to immature surfactant development in the lungs are the main causes of respiratory distress related to immaturity. Besides the respiratory distress syndrome, pneumonia and septicaemia and various lung malformations such as pulmonary hypoplasia or diaphragmatic hernia are the most common causes of neonatal respiratory problems. In all of these diseases the above mentioned mechanisms are important to recognize and support. Immaturity and insufficiency of these defense mechanisms in the newborn infant are the main indications for the various treatment applied for respiratory support in neonatal intensive care today. The respiratory support of sick newborn infants should therefore be directed towards the following:

1. Careful basic nursing considering temperature regulation, posture [7] and adequate energy supply with supplemental parenteral nutrition when this is needed.
2. Diagnosis and correction of disturbances which may affect respiration, e.g. infections, fluidelectrolyte-, metabolic-and acid-base imbalances.
3. Preventive respiratory stimulation, e.g. neurosensory stimulation through oscillating water beds or pharmacological therapy with methylx anthines (theophylline, coffein).
4. Maintenance of chest wall stability and lung mechanics with support of functional residual capacity through continuous positive airways pressure (CPAP) or respirator treatment with positive end expiratory pressure (PEEP) [8].

Pharmacological or surgical closure of persistent ductus arterious is important in respiratory care of preterm infants. Finally, endotracheal surfactant instillation has become possible in recent years and may have a major impact on the respiratory support in sick newborn babies during neonatal intensive care in the near future (9).

Acknowledgement

Supported by the Swedish Medical Research Council grant No. 4732, Research Foundation Samariten and First of Mayflower Foundation.

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