Foetal Lung Development

A brief outline of the stages of structural development of the pre and postnatal lung

Stage

0 to 7 Weeks
- Budding from the foregut.
- Developing of primitive pulmonary vein from left atrium.
- Developing of pulmonary artery.

8 to 16 Weeks
- Airway division commences.
- Adult pattern of vascularization has begun.
- Terminal bronchioles.
- Complete set of vessels that lead to respiratory bronchioles and terminal sacs.

17 to 27 Weeks
- 3 generations of respiratory bronchioles.
- Primitive saccule formation with type I and II epithelial cells (Surfactant).
- Capillarization.

28 to 35 Weeks
- Transitional alveolar ducts formed.
- 3 generations of saccules formed.

36 weeks
- Terminal saccules formed.

Postnatal 2 months
- 5 generations of alveolar ducts.
- Alveoli form with septation.

6 to 7 years of age
- Airways are remodelled.
- Alveolar sac budding occurs.

Upper Airways
- Heterogeneous.
- Conduct the airflow.
- Do not participate in gaseous exchange.
- Made up of nose, mouth, pharynx, and larynx.

Their function is to conduct, humidify, warm and filter air into the lungs and maintain patency.

Lower Airways

Made up of conducting airways of the intrathoracic trachea.

- Gas exchange parts of the terminal and respiratory bronchioles and alveolar ducts.
- Several functions of airway smooth muscle; controls airway lumen; appears to have the ability for airway reactivity in the presence of barotraumas.
- Narrowing of the airways increases the resistance to airflow which results in an increase in the work of breathing.

Thoracic and Respiratory Muscles

3 groups of muscles make up the 'respiratory pump' that moves air in and out of the lungs; diaphragm; intercostals and accessory muscles; abdominal muscles.

The diaphragm is innervated by the phrenic nerve and the resultant contraction pulls the muscle downwards and displaces the abdomen outwards and lifts up the thoracic cage.

The thoracic cage is then pulled inward. The resulting pressure changes are a reduction in intrapleural pressure and an increase in intra abdominal pressure.

Respiratory muscles fatigue when the energy consumption exceeds the energy available. Fatigue will occur when the Work of Breathing is increased.

When there is respiratory muscle fatigue an increase in carbon dioxide and apnoea result.

Postnatal Development

Lung size, surface area and lung volume grow for about 2 months postnatally. Control of breathing and neural maturation also continues to about 2 months postnatally. Volume and structural growth continues into early adolescence.

Control of Breathing

This is controlled by neural and chemical factors.

The respiratory centre, in the medulla of the brain, controls breathing.

Increases the rate and depth of breathing are detected by stretch receptors in the lungs. The expiratory centre inhibits the inspiratory centre resulting in stimulation of the expiratory muscles.

The respiratory centre sends nerve impulses via the phrenic and intercostal nerves, to the respiratory muscles. Inspiration results from this stimulus. When the stimulus stops, expiration occurs.

An increase in CO_2 is detected by the respiratory centre and results in an increase in the rate and depth of breathing.

An increase in blood pressure is detected by baroreceptors in the aorta and carotid arteries resulting in a decrease in the rate of breathing.

Proprioceptors in the muscles respond to movement and stimulate the respiratory centre, increasing the rate and depth of breathing.

The Hering – Breuer Reflex

Stretch receptors in the bronchi and bronchioles respond during excessive inspiration by sending messages to the respiratory centre to inhibit inspiration.

Initiation of Respiration

Respiration is the first function to be established. In utero the lungs are solid and fluid filled as they have not been inflated and aerated.

Breathing is initiated by a lack of oxygen and a high level of carbon dioxide in the blood stream. This stimulates the respiratory centre in the medulla of the brain.

Initiation of respiration is aided by the compression of the chest wall during the birth process; the cool air on the wet face; and the general handling of the body and limbs.

A healthy baby cries almost immediately, but he has to breath to be able to cry! With the first breath the blood vessels in the lung expand. Spontaneous breathing is now established.

Prior to inspiration there is no gas flow as the alveolar and atmospheric pressure are equal. For inspiration to occur alveolar pressure must be less than atmospheric pressure. Likewise for expiration to occur alveolar pressure must be higher than the atmospheric pressure.

Pulmonary Gas Exchange

Pulmonary venous return to the heart increases. This results in left arterial pressure exceeding right arterial pressure. Right to left shunting through the foramen ovale is reduced.

Oxygen is carried in the blood in two forms;

1. Physically dissolved in plasma.
2. Bound to haemoglobin.

Carbon Dioxide is carried in the blood in three forms:

1. Dissolved in plasma and red cells.
2. As bicarbonate.
3. Bound to haemoglobin.

This process involves both mechanical and chemical factors:

Intra Uterine Circulation

There are four temporary structures in the foetal circulation:

1. Ductus venosus. This vessel carries oxygenated blood from the umbilical vein to the heart for circulation throughout the foetus.
2. Foramen ovale. This is a temporary opening between the left and right atria in the foetal heart. This allows oxygenated and replenished blood to enter the left atrium and be pumped out through the aorta.
3. Ductus arteriosus. This vessel from the pulmonary artery to the descending arch of the aorta carries impure blood from the head and upper limbs. This bypasses the pulmonary circulation.
4. The hypergastric arteries. These two vessels branch off from the internal ileac arteries and become the umbilical arteries when they enter the umbilical cord. They return impure blood to the placenta for oxygenation and replenishment.

The changes in circulation at birth are due to the onset of respiration:

1. When the infant cries the lungs expand and their vascular field is increased
2. Blood, which has been passing through the ductus arteriosus to the aorta, now flows through the pulmonary arteries to the lungs for oxygenation.
3. The ductus arteriosus ceases to function within five minutes of birth, and at two months of age is automatically closed.
4. The foramen ovale closes when the increased blood flow to the lungs reduces and the pressure in the right side of the heart, and increases the tension in the left side. If this does not occur the venous blood in the right atrium will mix with the arterial blood in the left atrium and results in cyanosis.

Surfactant

Phospholipids synthesised in type ll cells lining the alveoli:

They form the air/liquid interface in the alveoli.

Surfactants play an important role in maintaining the stability at the end of expiration.

The absence of surfactant or the decreased levels lead to atelectasis and RDS.

Contributes to the important function of lowering alveoli surface tension.

Sources

- Identifiable in the foetal lung as early as 16 weeks.
- Surfactant is released into the alveoli in large quantities soon after the lungs are expanded with in the first few breaths.
- Surfactant synthesis and release is enhanced by the administration of antenatal steroid therapy.

Surfactant Preparations

Several preparations are commercially available but the main ones used are Survanta, Infasurf, Exosurf, and Curasurf.

- Survanta — Bovine source
- Exosurf — Synthetic
- Infasurf — Bovine source
- Curasurf — Porcine source

Functions of Surfactant

- Lines alveolar surface
- Lowers alveolar surface tension
- Prevents alveolar collapse
- Maintains residual lung volume
- Allows for easy lung expansion in the next inspiration
- Improves compliance
- Better oxygenation and ventilation
- Prevents leakage of fluid from alveolar capillary membranes
- Lowers inspiratory pressures
- Decreases Work of Breathing
- Defence mechanism against infections

Pulmonary Mechanics

The interaction between the ventilator and the infant is dependant on the mechanical properties of the respiratory system.

A pressure gradient between the airway opening and alveoli must exist to drive the flow of gases during both inspiration and expiration. This pressure gradient is determined by the compliance, resistance and inertance of the lungs.

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