Pulmonary ventilation teaching aid

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The biomechanical properties of the lungs and chest wall play an important role in ventilation. The biomechanical properties of compliance, elasticity, and recoil force are fundamental to an understanding of ventilation, but they are difficult concepts for many students to understand. Changes in these properties occur with some lung disorders, resulting in a change in the pattern of ventilation. The following information is designed to provide instructors with an inexpensive and effective aid for teaching these biomechanical properties. The materials needed for this demonstration are salad tongs and several rubber bands of various thicknesses (see Fig. 1).

Normal lungs exhibit inwardly directed elastic recoil; i.e., the lungs are in a stretched position and trying to decrease in size. An inwardly directed recoil force is present in a stretched rubber band. When given the opportunity the size of inflated lungs (or a stretched rubber band) will decrease. If the inwardly directed recoil force is unopposed, the lung will diminish in size (recoil) until it reaches the residual volume. This can occur with a pneumothorax.

In contrast, the normal chest wall exhibits outwardly directed elastic recoil, i.e., the chest wall is in a stretched position and trying to increase in size. An outwardly directed recoil force is present in salad tongs when they are used to pick up salad. If the outwardly directed recoil force of the chest wall (or salad tongs) is unopposed, it will increase in size. The unopposed chest wall will generally increase in volume (recoil) to ~70% of the vital capacity. This can occur with a pneumothorax.

Normally, the inwardly directed recoil force of the lungs opposes the outwardly directed recoil force of the chest wall. When the muscles of respiration are relaxed, the inwardly and outwardly directed recoil forces reach a balance. This “balance point” occurs at the end of a quiet exhalation. The volume of air left in the lungs at the balance point is equal to the functional residual capacity, i.e., the residual volume plus the expiratory reserve volume. The balance point concept can be demonstrated by placing a single rubber band around the two arms of the salad tongs. If you have chosen the right-size rubber band and salad tongs, the apparatus will find a balance between inwardly and outwardly directed recoil forces (see
As the muscles of inspiration contract, the chest wall expands and the volume of the lungs increases. This can be demonstrated by pulling the arms of the tongs apart. This movement stretches the lungs (rubber band), increasing the amount of inwardly directed recoil force while simultaneously decreasing the outwardly directed recoil force of the chest wall (salad tongs). You can show that this movement requires a muscular effort by releasing the arms of the salad tong. The cessation of the muscular effort allows the imbalance in the recoil forces to return the apparatus back to the balance point. This situation is similar to relaxation of the inspiratory muscles at the end of inhalation. As the muscles of inspiration relax the increased inwardly directed recoil force of the lungs is greater than the diminished recoil force in the chest wall. The increased inwardly directed recoil force is used to drive quiet (passive) expiration. Exhalation will continue until the opposing recoil forces are equal once again, i.e., back to the balance point.

The salad tong and rubber band contraption can be used to explain several changes that occur with obstructive and restrictive pulmonary disorders. Some resistive pulmonary disorders produce fibrosis in the lungs, resulting in an increase in elasticity (and a decrease in compliance). Adding a second rubber band to the salad tong can be used to show the effect of pulmonary fibrosis. The students can visually see that there are more rubber bands present (an increase in elasticity and a decrease in compliance). This situation makes inhalation more difficult by requiring more muscular effort to move the chest wall (spread the arms of the salad tongs) and inflate the lungs (stretch the rubber bands). The increase in inwardly directed recoil force also helps to explain why people with this condition can exhale so quickly.

Obstructive pulmonary disorders, e.g., emphysema, produce anatomical changes in the lungs that result in a decrease in the elasticity (an increase in compliance) of the lungs. This can be demonstrated by using a thinner rubber band than was used for the normal state (see Fig. 3). The students can see that the thinner rubber band has fewer elastic fibers and is more compliant. When a thinner rubber band is used with the salad tongs, several changes in ventilatory mechanics can be demonstrated. First, inhalation is easier because the lungs are more compliant; i.e., less effort is required to spread the arms of the salad tongs. Second, the inwardly directed recoil force of the lungs, used to drive exhalation, is reduced, resulting in a prolonged exhalation. Third, a “new” balance point is found between the rubber band (lungs) and the salad tongs (chest wall). The spread of the salad tong arms is increased at the new balance point (compare Figs. 2 and 3). This can be used to demonstrate why people with emphysema may appear “barrel chested” or “overinflated”. The decrease in elasticity of the lungs results in a new balance point between the normal, outwardly directed recoil force of the chest wall and the diminished, inwardly directed recoil force of the lungs. The change in recoil forces results in an increase in the functional residual capacity.

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A simple model for understanding cohesive forces of the intrapleural space

The concept and physiological significance of the cohesive forces of the intrapleural space are often difficult for students to grasp. To help students understand this concept, a simple model is often utilized. Students are told that the outer surface of the lung is lined with a membrane called the visceral pleura, and the inside of the thorax is lined with a membrane called the parietal pleura.
These pleural membranes juxtapose to form a pleural sac around the lung. The space within the pleural sac contains a few milliliters of fluid. The intrapleural fluid holds the visceral and parietal pleura together. The model utilized to facilitate the understanding of this concept is two microscope slides with a few droplets of water placed between them. The slides move easily over one another horizontally; however, it is very difficult to pull them apart perpendicularly. Similarly, intrapleural fluid creates a slippery surface, allowing the lungs to slide within the chest against the thoracic wall. In addition, when the chest expands during inspiration, the lungs are compelled to follow so that the lungs and chest expand as a single unit. Thus, when the diaphragm contracts and increases thoracic volume, the lung slides against the thoracic wall and lung volume increases by a similar amount. Students’ eyes light up when these concepts are illustrated with this simple model.

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