Mechanism Producing Subglottic Air Pressure While Swallowing
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Abstract

Background: The importance of subglottic air pressure during the swallow is recognized, yet no experiment has sought to determine the mechanism that generates this pressure. We hypothesized that lung-thoracic recoil forces are responsible for this pressure.

Objectives: To compare direct subglottic air pressure measurements obtained while swallowing at different lung volumes with airway pressures obtained by total system recoil measurements.

Methods: Direct measurement of subglottic air pressure during swallowing was obtained via a percutaneous puncture of the cricoidthyroid membrane. Tidal volume was measured via a nasal mask. Next, to model swallowing, airway pressure was measured from a mouthpiece by occluding the airflow for a duration that is consistent with total vocal fold closure during swallowing. Passive exhalation was used to reproduce central inhibition of respiratory muscles that occurs during the swallow.

Results: Regression analyses on the combined data showed strong linear relationships between lung volumes (X) and airway pressures (Y) with overall goodness of fit which were highly significant (p < 0.0001). R² Square values ranged from 0.78 to 0.91.

Conclusion: The subglottic air pressure that is generated during a swallow is likely generated by lung-thoracic unit recoil forces that become active when respiratory muscles are inhibited. The degree of subglottic pressure generated is directly related to lung volume. The influence of the respiratory phase and recoil forces may alter the effects of therapeutic interventions intended to increase subglottic pressure such as tracheostomy tube occlusion and decannulation.

Methods and Materials

Introduction

• Recent investigations have established that subglottic receptors have a measurable influence on swallowing motor control [1,2]. Consequently, sufficient positive stimulation of subglottic mechanoreceptors before and during the swallow may be necessary to optimize swallowing function.

• Previously, a single-subject pilot study determined that subglottic air pressure could be detected and measured while a healthy, non-tracheostomized, non-anesthetized person swallowed semi-solids [3].

A linear relationship was found with highest lung volumes exhibiting the highest positive pressures and the lowest lung volumes showing lower pressure readings. Swallows occurring below functional residual capacity (FRC) were negative pressure values. It was postulated that the change in polarity of the pressure measured above and below FRC indicated that deglutitive subglottic air pressure must be generated by lung-thoracic recoil forces; however recoil measurements were not made during that experiment.

• We hypothesized that a modified airway interrupter technique would generate accurate lung-thoracic unit recoil pressure and lung volume graphs that could be used to non-invasively predict subglottic pressure levels that occur when swallowing.

Part I: Deglutitive subglottic pressure measurements

• Direct measurement of subglottic air pressure during swallowing was obtained via a percutaneous puncture of the cricoidthyroid membrane. The needle was withdrawn leaving a catheter that was then connected to a pressure transducer.

• Tidal volume was simultaneously measured via a pneumotachometer attached to a nasal mask.

• Participants swallowed 5 ml pudding boluses at four randomly assigned estimated lung volumes: Total lung capacity (TLC), tidal volume (TV), functional residual capacity (FRC) and residual volume (RV).

• Pressure-volume graphs were then generated after FRC values were added to the tidal volumes (see Part I).

Part II: Pulmonary function testing

• Lung volumes, including the determination of functional residual capacity were measured using a calibrated body box plethysmograph and commercially available software.

Part III: Modified interrupter technique

• To model swallowing, airway pressure during passive exhalation was measured at the mouthpiece by occluding the airflow for a duration that is consistent with average true vocal fold closure during swallowing (650 ms).

• Passive exhalation was used to reproduce central inhibition of respiratory muscles that occurs during the swallow.

• Bipolar EMG recording was used to assure that abdominal muscles did not assist with exhalation.

• Pressure – volume graphs were then generated.

Conclusions

The subglottic air pressure that is present during a swallow is generated by lung-thoracic unit recoil forces that become active when respiratory muscles are inhibited. The degree of subglottic pressure generated is directly related to lung volume and lung-thoracic unit recoil forces.

References

