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Disordered Coordination of Deglutition and Respiration in Chronic Obstruction Pulmonary Disease

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Introduction

Deglutition and respiration share the upper aerodigestive tract. Because both systems are housed within the same anatomical structures, proper utilization of protective mechanisms is crucial to prevent airway compromise during a swallow. Both systems coordinate in a meticulous manner to ensure proper timing and movement of the oropharyngeal structures for laryngeal closure and lower airway protection (Hegland, Huber, Pitts, & Sapienza, 2009). Chronic Obstructive Pulmonary Disease, commonly referred to as COPD, is a wide-ranging term used to describe progressive lung diseases including emphysema, chronic bronchitis, refractory (i.e., severe, persistent) asthma, and some forms of bronchiectasis. Individuals with COPD experience chronic airflow limitations with episodes of acute worsening of airflow obstruction that are associated with infections (Decramer, Janssens, & Miravitlles, 2012). Because of the complex anatomic and functional relationship between swallowing and respiration, it is logical to question whether this relationship is disrupted when pulmonary function is compromised. The coordination of breathing and swallowing may be particularly important to patients with COPD because prandial aspiration (i.e., result of food or liquid entering the airway) (Murry & Carrau, 2012) may be a factor that sets off exacerbations of the disease. Conversely, exacerbations of COPD may promote aspiration, thereby increasing the severity (Gross, Atwood, Ross, Olszewski, & Eichhorn,

2009). The following evidence suggests that within the COPD population, there are compromised swallowing mechanisms pertaining to the coordination of breathing and swallowing, leading to more frequent aspiration, resulting in more exacerbations of the disease.

The Typical Swallow

A review of the anatomical and physiological mechanisms of swallowing within healthy individuals is critical for the understanding of the complex swallowing relationship that develops in people with COPD.

In healthy individuals, the swallowing process can be divided into four phases. They include the oral preparatory, oral, pharyngeal and esophageal phases. Although each phase of swallowing has separated physiological and anatomical characteristics, they also work interdependently with the previous and following phases (Murry, & Carrau, 2012); muscle and pressure systems all work together while fulfilling their individual duties to ensure a safe, efficient swallow (Seikel, King, & Drumright, 2010).

The air pressure and muscular system utilized during a typical swallow is commonly referred to as the oral sling. This system enables the bolus to move against gravity down to the esophagus and begin its journey down the digestive tract (Murry & Carrau, 2012). Remarkably, the respiration and deglutition systems are synchronized in a manner to avoid penetration and aspiration of unwanted substances into the

airway, potentially to the level of the bronchi and lungs (Cvejic et. al., 2001).

Oral Preparatory Stage

The first stage of swallowing is the oral preparatory stage. This stage actually begins before food enters the mouth. An individual's sense of smell, along with the anticipation of food causes the salivary glands to produce more saliva to aid the mastication process of swallowing (Sayadi & Herskowitz, 2010). This process is crucial for one to breakdown the substance that he or she is trying to consume in a safe manner.

Under the oral preparatory phase, mastication takes place as our lips, cheeks, teeth and saliva work together to break down the substance (Sayadi & Herskowitz, 2010). During a sequenced arrangement of events, the tongue arranges the substances and moves it posteriorly to a position where it can be chewed, ground and mixed with the saliva to form the bolus that eventually will be swallowed (Murry & Carrau, 2012). The time it takes to complete this stage of swallowing can vary depending upon many factors. Individual characteristics, such as oral muscular strength and dentition can affect the timing and overall success within the oral preparatory phase (Murry & Carrau, 2012). Characteristics of the substance being consumed, such as texture, size, and consistency can also play a factor in the amount of time it takes to chew or prepare the bolus for the next stage of swallowing (Hiss, Strauss, Treole, & Stuart, 2004).

Oral Stage

The oral stage begins when the bolus is in place for the swallow. Several processes must occur sequentially during this phase (Seikel et al., 2010). At this time, the tongue, palate, teeth and cheeks transfer the bolus posteriorly on the tongue to the back of the oral cavity (Murry & Carrau, 2012). The velum then elevates as the lips and buccal muscles contract to build pressure and reduce the volume of the oral cavity. The posterior tongue is then depressed, and the anterior and middle portions of the tongue differentially elevate and begin the propulsion of the bolus to the oropharynx (Murry & Carrau, 2012). This entire process happens in about one second (Sayadi & Herskowitz, 2010). Once the bolus is past the point of the base of the tongue, we have successfully completed the oral stage of swallowing and move into the next phase.

Pharyngeal Stage

The pharyngeal stage consists of a complex sequence of reflexively controlled events. This phase of swallowing begins when the bolus reaches the level of the faucial pillars. During this time, the swallowing reflex is initiated (Seikel et al., 2010). The swallowing reflex is crucial in order to maintain the correct order of events to assure a safe swallow while avoiding aspiration and penetration. This reflex coordinates the many muscles required to push the food down into the esophagus while acting as a safety net, cueing the epiglottis to fold over the trachea to keep the bolus from penetrating the vocal folds and potentially entering

the respiratory tract (Sayadi & Herskowitz, 2010). While the epiglottis is the main protector of the airway, the vocal folds close tightly to work as a backup plan to avoid aspiration of any misdirected substances. Once the vocal folds are completely adducted for the swallow, respiration briefly stops. This natural state is known as swallowing apnea (Seikel et al., 2010). The transitory swallowing apnea lasts approximately 0.05-1.0 seconds (Hiss et al., 2004). During this time, the epiglottis is covering the airway and the vocal folds are shut to allow the bolus to pass through the pharynx and into the esophagus (Murry & Currau, 2012). This is a critical defense mechanism against aspiration, which can be extremely hazardous to our lungs and respiration system if infection were to occur (Murry & Currau, 2012).

Murry & Carrau, (2012) provide information regarding the typical swallowing process. They found that when one engages in deglutition, he or she will experience a sudden decrease in airflow. This decrease in airflow leads to a short interval of apnea. Research suggests that the time in which apnea is experienced is reliant on the state of the patient, bolus size, the age of the patient, and whether the swallow is cued or spontaneous (Murry & Carrau, 2012). For most healthy individuals without dysphagia, single swallows are followed by a period of expiration. A study done by Hegland et al. (2009) revealed that the expiration-apnea-expiration pattern of breathing is present in 71%-100% of healthy individuals. Research supports that rate and time of the stoppage of

breathing is well coordinated with the normal swallow (Murry & Carrau, 2012). A well coordinated event is crucial to avoid aspiration and penetration (Gross et al., 2009).

Once the bolus reaches the laryngopharynx, it passes over the epiglottis. The bolus is then divided into two roughly equal masses, passing to either side of the larynx, through the pyriform sinuses, to recombine at the esophageal entrance. At this point the esophageal phase takes over (Seikel et al., 2010).

Esophageal Stage

Before digestion takes place, the final stage of swallowing, the esophageal stage, must run its course. This stage of swallowing is purely reflexive and is not within voluntary control (Seikel et al., 2010). During this final stage of swallowing, the bolus passes through the pharyngeal cavity and into the esophagus (Seikel et al., 2010). There, the upper esophageal sphincter (UES) works in coordination with the swallowing reflex to allow the bolus to enter the esophagus and out the lower esophageal sphincter (LES) by wavelike contractions and a gravity system referred to as peristalsis (Murry & Carrau, 2012). Once the swallowing reflex is initiated during the pharyngeal stage of swallowing, signals are sent to the UES and LES to begin preparing for the bolus. The bolus is then transferred into the digestive tract (Murry & Carrau, 2012). Once the bolus is delivered to the digestive tract, the swallow is

considered complete (Sayadi & Herskowitz, 2012). This whole stage of swallowing happens within 10 to 20 seconds (Seikel et al., 2010).

As discussed previously, a safe swallow can only be achieved when the body is able to coordinate both the deglutition and respiratory systems (Gross et al., 2009). Typically, individuals are voluntarily and involuntarily able to coordinate both systems very easily (Hegland et al., 2009). When we are consuming food and liquids, not much thought occurs as to what's taking place anatomically and physiologically. We are normally only concerned with how the food or drink tastes and what we are physically and mentally gaining from the substance being consumed (Sayadi & Herskowitz, 2010). To reiterate the coordination process, Gross et al. (2009) states that within healthy individuals, swallowing interrupts the expiratory phase of respiration and prompts an apneic pause of about one second before respiration resumes with expiration, which is then followed by an intra-esophageal stripping action from the pharynx to the stomach. A study done by Gross et al., (2009) revealed that 90% of their healthy participants followed their swallows with an exhalation, indicating an exhale-swallow-exhale pattern. In an additional study conducted by Mokhlesi, Logemann, Rademaker, Stangl, & Corbridge, (2002), it was found that during clinical observations of healthy adults, breathing and swallowing functions were well coordinated, this coordination being most evident at the level of the larynx. Thus, when all systems work properly, a coordinated, safe,

sufficient swallow takes place. When one or both systems are altered or disordered, redirection of consumed substances is likely to occur (Gross et al., 2009).

Chronic Obstruction Pulmonary Disease (COPD)

Chronic Obstruction Pulmonary Disease, commonly referred to as COPD, affects between 12 and 24 million individuals in the United States. The disease has rapidly made its way to the top of the charts, becoming the leading cause of death in the U.S. today (Torpy & Goodman, 2012). COPD is currently defined as a "preventable and treatable disease with some significant extra pulmonary effects that may contribute to the severity in individual patients" (Decramer et al., pg. 1341). Characteristics of the disease include progressive airflow obstruction that is only partly reversible, inflammation in the airways, and systemic effects or comorbidities. Comorbidities of the disease include ischemic heart disease, diabetes, and lung cancer. Although the exact etiology is yet to be identified, doctors suggest that the main cause is associated to smoking tobacco. However, other factors such as genetic determinants, lung growth and environmental stimuli have been identified as potential causes (Decramer et al., 2012).

Exacerbations of the Disease

One of the most common characteristics associated with COPD is exacerbation of symptoms. Exacerbations typically reduce quality of life, speed the progress of the disease and increase the risk of death

(Decramer et al., 2012). Exacerbations are "short periods (at least 48hours) of increased coughing, dyspnea and production of phlegm that can become infected" (Decramer et al., p. 1343). There are approximately 15 million exacerbations each year, leading to 2 million hospitalizations (Decramer et al., 2012).

Exacerbations can range from mild to severe in status. Mild exacerbations may require an increased dose of bronchodilators, moderate exacerbations may require treatment with systemic corticosteroids, antibiotics, or both, and severe exacerbations frequently necessitate admission to hospital for an extended amount of time (Decramer et al., 2012). For individuals with severe COPD, their disease typically becomes further aggravated by these exacerbations, up to 78% of which are due to bacterial infections, viral infections, or both (Decramer et al., 2012). In addition to infections, it has also been suggested that aspiration may be an additional cause of exacerbations in some patients; however, there is little data supporting that this relationship exists at this time (Mokhlesi et al., 2002).

Symptoms, Diagnosing & Treatment

Individuals with COPD experience a wide variety of symptoms throughout the progression of their disease including shortness of breath, coughing and wheezing, decreased blood oxygen levels and increased carbon dioxide levels, exercise intolerance and excess phlegm production (Torpy & Goodman, 2012). A person's COPD may be mild

and unrecognized for several years until symptoms exacerbate (Torpy & Goodman, 2012). COPD can be diagnosed using a variety of assessments and tools. Doctors may measure breathing volumes and possibly conduct a test called spirometry that measures lung function (Decramer et al., 2012). Sometimes a bronchodilator (inhaled medication to widen the airways) is given during the test to give more detailed results. Blood-oxygen level can be measured indirectly using pulse oximetry, which measures the oxygen saturation of hemoglobin through the surface of the skin or fingernail, or directly by a sample of blood from the artery (Torpy & Goodman, 2012). A chest x-ray can also be helpful in determining the amount of lung damage and can also indicate pneumonia or other lung disease (Torpy & Goodman, 2012).

The best treatment for COPD as well as any lung disease is to stop smoking or being around second-hand smoke, due to irritant action in the airway (Decramer et al., 2012). According to Decramer et al., (2012) Cessation of smoking slows progression of disease as well as lowers mortality rate by 18%. Some medications such as bronchodilators (used to widen the air passages) are recommended for patients with COPD (Torpy & Goodman, 2012). Other medications include steroids, used to reduce inflammation, and antibiotics used to treat potential infections. Typically, these medications will be used in combination. Some people may require oxygen during the night, while engaging in physical activity, or all of the time depending on the severity of their disease. Pulmonary

rehabilitation, including exercise, may also help to improve functional status (Torpy & Goodman, 2012) In addition, some vaccines can help to prevent or minimize other lung diseases, such as influenza or pneumococcal disease (Decramer et al., 2012).

Swallowing With COPD

Many deglutition and swallowing characteristics that differ from the typical or normal swallower have been identified within individuals who have COPD. Abnormalities impacting functional swallowing status and presenting an aspiration risk for patients with COPD include reduced laryngeal elevations with delayed laryngeal closure, reduced laryngeal-pharyngeal sensation, impaired pharyngeal clearance, cricopharyngeal dysfunction, and gastroespohageal reflux disease (Cvejic et al., 2011). In addition, two main swallowing characteristics found within individuals with COPD, disruption of the exhale-swallow pattern and an abnormal swallowing reflex, result in hazardous swallowing situations that can lead to more frequent aspiration.

Disruption of exhale-swallow-exhale pattern

It has been observed that healthy individuals engage in a strongly preferred exhale-swallow-exhale pattern during deglutition (Gross et al., 2009). A disruption in this pattern, such as inhaling after the swallow, could increase the risk for aspiration (Murry & Carrau, 2012). The risk for aspiration increases as the negative pressure of inhalation has the potential to draw food and liquid residue towards the lungs (Gross et al.,

2009). As Gross et al., (2009) pointed out, swallowing during early inhalation, late exhalation, or during the transition from exhalation to inhalation, results in decreased subglottic air pressure. The authors claim that the reduced subglottic air may impact swallowing by prolonging the pharyngeal contraction duration and slowing bolus transit time, as well as increasing amounts of pharyngeal residue and aspiration.

According to Gross et al. (2009), having low or decreased subglottic air pressure in addition to COPD only further complicates the coordination process of the swallow. A study conducted by Gross et al., (2009) indicated that participants with COPD swallowed more frequently during inhalation than when compared to healthy participants. In the study, 25 healthy subjects were compared to 25 subjects with a diagnosis of COPD. Patients where observed using the KayPentax Swallowing Station. This laboratory tool provided researchers with the means to simultaneously record respiratory and surface electromyography (electrical activity produces by skeletal muscles) processes (Gross et al., 2009). Participants were asked to consume various types of substances ranging from pureed, pudding textures to soft masticated consistencies. The study revealed three patterns of impaired breathing and swallowing coordination for people with COPD. First, when consuming a bolus that required mastication, the frequency with which swallows occurred during inhalation was significantly greater.

This disordered characteristic of swallowing poses a threat to ones respiratory tract as food and liquid can be drawn inward during inhalation. Second, when participants were asked to swallow the semi-solid pudding, a significant amount of the swallows were also followed by inhalation, once again suggesting a disordered swallowing breathing pattern. Third, COPD participants swallowed at low tidal volume (TV) at a significantly higher rate than the healthy volunteers (Gross et al., 2009). Swallowing at a low TV frequently results in more attempts or gasps for air after the swallow. As residue may remain in the pharyngeal cavity or in the mouth after the swallow, gasping for air can result in more frequent aspiration or penetration of unwanted substances (Gross et al., 2009). Results from an additional study conducted by Gross et al., (2009) indicated that patients with COPD are more likely to swallow during inhalation while swallowing solid foods. The study also suggested that post-swallow inhalation occurred significantly more often in the COPD population as opposed to healthy individuals. These results suggest a greater likelihood of aspiration when swallowing with COPD.

Cvejic et al. (2001) hypothesized that as a result of limited ability to maintain normal breathing-swallow patterns, penetration with or without aspiration of pharyngeal contents during swallowing is increased in patients with COPD. Their study compared 16 subjects diagnosed with COPD with 15 age-matched, healthy participants. Each patient's swallows were assessed using a standard videofluoroscopy swallow

protocol. Hyoid elevation and respiratory swallow patterns were observed. Results from this study indicated that normal protective mechanisms during swallowing might be compromised in people with COPD. This functional abnormality may further impact respiratory health in individuals with COPD. Results also indicated a significant amount of aspiration and penetration in the individuals with COPD when compared to the control group of healthy individuals (Cvejic et al., 2001).

Shaker et al., (2008) stated that according to their research, tachypnea, aging, bolus volume and COPD modify the close coordination between deglutition and respiration. The researchers concluded that patients experiencing COPD exacerbations swallowed significantly more often by interrupting the inspiratory phase and resumed their respiration significantly more with inspiration, which may further worsen the overall symptoms.

Further research continues to show evidence that individuals with COPD have difficulty coordinating swallowing and breathing patterns. An additional study done by Gross et al., (2009) revealed that patients with COPD may be prone to disrupted breathing and swallowing patterns because of the combined effects of deglutive apnea and reduced ventilator capacity (Gross et al., 2009). During the time of and around the time of the swallow, the protection of the airway, and ultimately the respiratory system heavily depends on the successfulness and coordination of breathing and swallowing (Gross et al., 2009). These

studies expose the characteristics of COPD that ultimately affect a person's ability to coordinate crucial breathing-swallowing patterns during swallowing.

Abnormal Swallowing Reflex

Impairment in swallowing reflex is directly associated with increased risk of silent aspiration and pneumonia (Terada et al., 2010). A cross-sectional survey revealed that the swallowing reflex was more frequently impaired in patients with COPD than in healthy subjects. Terada et al. (2010) reported a high prevalence of abnormal swallowing reflexes among subjects with COPD who had experienced exacerbations in the previous year than those without exacerbations (Terada et al., 2010). As aspiration in COPD becomes increasingly more pronounced as the disease progresses exacerbations of the disease also increase, creating a vicious cycle (Gross et al., 2009).

A study conducted by Terada et al. (2010) investigated the swallowing reflex in 67 patients with COPD compared to 19 age-matched controls. The swallowing reflex was evaluated using a simple two-step swallowing provocation test. The swallowing response and the latent time for swallowing were observed in participants in the supine position after administering a bolus of 0.4 ml or 2.0 ml of distilled water to the larynx through a nasal catheter with a 0.5 mm internal diameter. Results from this study indicated an abnormal swallowing reflex in

subjects with clinically stable COPD. These swallowing abnormalities were associated with frequent COPD exacerbations.

Evidence of increase in morbidity (i.e., incidence of disease) and mortality (death rate) indicate the impact of exacerbations on the progression of COPD is severe. According to Terada et al. (2010), one of the most common causes of COPD exacerbations is tracheobronchial infection (Terada et al., 2010). Therefore, apparently having an abnormal swallow reflex increases the chance of aspiration, therefore supporting the claim of a high correlation of aspiration in regards to individuals with COPD.

Conclusion

A disruption in the coordination of the breathing-swallowing sequence can lead to penetration and aspiration of unwanted substances into the respiratory tract. Individuals with COPD have breathing challenges due to constricted airways and additional symptoms of the disease. The coordination of breathing and swallowing is particularly important to the COPD population because prandial aspiration may be a factor that sets off an exacerbation of the disease. Exacerbations can speed the progression of the disease. Research stated previously within the COPD population has revealed numerous aspects of an individual's swallow that are considered abnormal. Several studies indicated that people with COPD will not only have difficulty coordinating the respiration and swallowing (Cvejic et al., 2011; Gross et al., 2009), but

also expose actual disordered physiological characteristics that will have an impact of achieving a safe and sufficient swallow (Mokhlesi et al., 2002).

Additional research in the field of COPD, aspiration, deglutition and respiration is critical for improvement of SLP services. It is important to be aware of swallowing characteristics in individuals with COPD that differ from the healthy-swallowing population so that proper therapy and precautions can be taken during exacerbations of the disease.

Future Directions

While many studies have been conducted with the COPD population, a lack of evidence still remains concerning swallowing function as it relates to aspiration and exacerbations of the disease. Articles pertaining to the COPD population written by Mokhlesi et al., (2002), Gross et al., (2009), and Cvejic et al. (2011), all comment on the lack of current research based evidence to link aspiration and dysphagia to the COPD population as well as the need for further extensive research in the area. Future studies should be conducted to solidify the correlation of aspiration, deglutition, respiration, COPD and exacerbations of the disease. Future research should include an in-depth look at aspiration occurrences as it compares to healthy individuals. Studies should also determine whether patients with varying severities of the disease exhibit individual protective maneuvers

against aspiration. Additional studies could include the use of videofluoroscopic tools with simultaneous airflow measurements to identify the exact anatomical and physiological nature of the swallowing system and the respiratory system within this population. Finally, it would be interesting and relevant to the SLP population to investigate how commonly utilized swallowing therapy maneuvers, such as the effortful swallow and Mendelsohn maneuver, would impact the swallow-respiratory relationships with individuals who have COPD.

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