The Interthoracic Connection

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Introduction

In the age of healthcare reform licensed therapists, clinicians and other healthcare providers must work together to achieve our patients' goals and maximize outcomes. This article will highlight the shared roles of Respiratory Therapists, Physical Therapists and Speech Language Pathologists working with the muscles used for trunk and posture control, respiration and breath support. An emphasis on this interthoracic connection results in positive effects on airway protection, cough strength, swallow and phonation.

Review of Respiratory System

Respiration is a complex neurological process originating in the respiratory center of the brain, specifically at the pons and medulla oblongata. A signal is sent to the diaphragm, the primary breathing muscle, to contract. With contraction, the diaphragm moves downward creating negative pressure in the thoracic cavity, drawing air into the lungs through the nose and mouth.

Exhalation is typically passive. As the diaphragm relaxes it moves upward, gently moving the air from the lungs and out through the nose and mouth.

Although the diaphragm is responsible for approximately 2/3 of our tidal volume[1] it does not work alone. The intercostals are responsible for chest expansion which allows the lungs to fill, and stabilization of the ribcage. When additional tidal volume is required, accessory muscles also contribute. Accessory muscles may be activated to increase tidal volume or to compensate for a weak diaphragm. These accessory muscles include scalene, trapezius, pectoralis major, sternocleidomastoid and the abdominals. Accessory muscles may also be recruited to assist in exhalation in times of respiratory distress, diaphragm paresis and to assist in upward movement of the diaphragm.

Posture and Trunk Control

Many of the same muscles used for respiration are also used for trunk control and posture, including the diaphragm, intercostals and abdominals. The central nervous system coordinates these multipurpose muscles.

Numerous daily tasks require trunk control, such as breathing, coughing, eating, talking, walking and bowel and bladder emptying. Sitting upright requires trunk support and is a result of anterior pelvic tilt, shoulder abduction and protracted shoulders. This upright posture encourages upper chest breathing and use of accessory muscles of respiration. This posture is necessary for adequate respiration, secretion clearance and breath support for speaking.

Slouched posture is a result of a posterior pelvic tilt and shoulder adduction/protraction. A chronically slumped posture can cause a multitude of postural-related deficiencies including:

- Restricted breathing mechanics
- Compromised swallowing mechanics which increases the risk of aspiration
- Mechanically compromised recruitment of accessory muscles necessary for increased lung volumes
- Impaired diaphragm mechanical advantage

Position supports to encourage upright sitting posture include:

- Longitudinal towel rolls for increased ribcage expansion and posture support
- Iron cross position results in stretching of the pectoral and bicep muscles, increased chest excursion and lung volume expansion (LVE).
- Abdominal binder (ensure that the binder is properly positioned to avoid restriction of the rib cage)

The Body's Closed System

The human body is designed as a perfectly closed system. The trunk has the thoracic and abdominal cavities and is completely separated by the diaphragm. The trunk is sealed at the top by the vocal folds and at the bottom by the pelvic floor muscles. Due to this closed system, we are able to generate and maintain interthoracic pressure (also known as the Valsalva maneuver) which is necessary for trunk power, posture control, balance, lifting, bowel and bladder control, coughing, gastromotility and to regulate abdominal pressure. These functions are impaired or absent when there is a breach in this closed system. A breach may exist due to weakened trunk or pelvic floor muscles, compromised vocal folds or the presence of an endotracheal or tracheostomy tube.[2]

Impact of a Tracheostomy Tube

When the closed system is breached due to placement of a tracheostomy tube, the impact is considerable. A tracheostomy tube is inserted below the level of the vocal cords, which changes the airflow and bypasses the entire upper airway. Lack of airflow results in loss of sensation in the oropharynx, decreases the senses of smell and taste and eliminates the

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natural ability to humidify our inhaled air. Without airflow through the vocal folds, there is little to no opportunity for phonation. An open tracheostomy tube creates a constant leak in our closed system and prevents glottis closure. Adequate subglottic pressure is necessary to achieve vocal loudness, sustained sounds and varied voice frequency. Subglottic pressure is measured in cmH2O and can be measured using a cuffolator or NIF (negative inspiratory force) manometer. Conversational speech requires subglottic pressures between 5-10 cmH2O and a normal swallow approximately 7-10 cmH2O.[3]

Airway Patency and Secretion Clearance

A successful cough requires both inspiratory and expiratory muscle strength. Simply put, one needs to take in a big breath and blow out forcefully to cough effectively. Inspiratory muscle strength may be easily determined using an Incentive Spirometer to measure inspiratory capacity (IC). Peak expiratory cough force (PECF) is one way to measure expiratory strength. The standard-of-care for persons with asthma includes the use of a Peak Flow Meter to measure peak expiratory flow (PEF). A Peak Flow Meter may also be used to measure PECF as an indicator of expiratory muscle strength. An average adult PECF is approximately 300/lpm and a productive cough requires greater than 170/lpm.[4] PECF is also used as an indicator for readiness for trach decannulation.

Various pulmonary function tests (PFT) may be performed to assess respiratory muscle strength, such as maximum inspiratory pressure (MIP) or negative inspiratory force (NIF) and maximum expiratory pressure (MEP); however, "cough peak flow (CPF) is an acceptable alternative to measuring maximal expiratory flow (MEP) in assessing expiratory muscle weakness in these patients especially as performing the MEP can be quite cumbersome."[5]

Expiratory muscle strength training (EMST) has been shown to "increase expiratory muscle strength, improve cough function, positively affect speech characteristics and promote swallow performance in clinical populations."[5] There are numerous inspiratory and expiratory training devices available that can be incorporated into any discipline's care plan to maximize the strength training effect.

The breech in the closed system due to tracheostomy tube placement has a significant impact on airway patency and secretion clearance. Without the requisite subglottic pressure, a patient with an open trach is unlikely to generate enough internal pressure to produce an effective cough, relying instead on oral and tracheal suctioning. This results in an increased risk of atelectasis, infection, pneumonia and returns to an acute care setting with a prolonged length of stay (LOS).

An individual with an open tracheostomy tube is unable to perform, and therefore benefit from, the described maneuvers to measure inspiratory and expiratory muscle strength or the respiratory muscle trainers.

Restoring a Closed System

The ability to restore a closed system for a tracheostimized patient will typically create the necessary subglottic pressure to generate and maintain the desired internal pressure. Once the closed system is restored, many if not all, of the functions lost due to trach tube placement will return.

One mechanism for recreating a closed system is with the use of a Passy Muir Valve (PMV). Invented by a patient named David Muir, the Passy-Muir Tracheostomy & Ventilator Swallowing and Speaking Valve is a simple medical device used by tracheostomy and ventilator patients. When placed on the hub of the tracheostomy tube or in-line with the ventilator circuit, the PMV redirects exhaled air flow through the vocal folds, mouth and nose enabling voice and improved communication. Years of evidence-based research has shown that the PMV offers patients numerous clinical benefits beyond communication, including: improved swallowing, secretion management, oxygenation, smell and taste and infection prevention and overall quality of life. Early introduction and use of the PMV has also been shown to facilitate ventilator and trach tube weaning and pediatric speech/ language development.

Ventilator patient with PMV using an expiratory muscle trainer.

To summarize thus far, there is an interthoracic connection of posture and trunk control to respiration and breath support for speech; and although the body's closed system can be impacted by a trach tube, the placement of a one way speaking valve can restore positive airway pressure.

For persons needing a tracheostomy tube for an extended length of time, clinicians focus on enhancing quality of life through rehabilitation and use of the PMV, which can facilitate patient participation.

Tracheostomy Tube Patients and Rehabilitation

The most common goals for persons in rehabilitation are to maximize their independence and return to their life roles. The following case example will demonstrate the benefits associated with the application of the principles outlined in this article.

Case example: Scott C., a 35-year-old husband and father of two young children

- Scott was diagnosed with Guillain Barre Syndrome and spent two weeks at an acute care hospital.
- When he transferred to Madonna Rehabilitation Hospital's long term acute care hospital (MLTCH), Scott was on a mechanical ventilator, unable to communicate and paralyzed from the neck down.
- Within 24 hours of admission, Scott was co-evaluated by his Speech Language Pathologist and Respiratory Therapist for assessment to initiate the PMV.
- Within 12 days of his admission Scott was completely weaned from the ventilator.
- Six days later his tracheostomy tube was removed.
- Additional goals for Scott included: independence with

Already weaned from the ventilator and trach tube, Scott continues to make progress through inpatient rehabilitation.

transfers and activities of daily living (ADL), increase activity tolerance, increase wheel chair sitting time to four hours for participation in community outings, improve his speech and be able to direct his own cares.

- After four weeks on MLTCH, Scott transferred to Madonna's inpatient Acute Rehab Hospital for another two weeks, with three hours of therapy each day.
- Scott met all of his inpatient goals and was discharged to Madonna's Outpatient program for four weeks of additional Rehabilitation.

Almost four months after the acute onset of his symptoms, Scott went home to his family. He returned to work and resumed his home roles. He even ran a 5K race to raise awareness of Guillain Barre.

Scott was able to meet his goals through the incorporation of interdisciplinary interventions and a collaborative, team approach to rehabilitative care. Specifically:

Introducing the PMV early. The benefits of the PMV for Scott were both physiologic and psychosocial. He was able to communicate his needs to his caregivers, speak with family and friends over the phone and avoid the isolation and depression that often affect those on mechanical ventilation.

Restoring Scott's closed system with the PMV reduced the frequency of invasive tracheal suctioning. He was able to increase his oral intake without increasing aspiration risks. The posture and trunk control therapy contributed to his lung volume expansion and postural muscle strength, allowing Scott to tolerate an upright position during these activities.

Application of the PMV also facilitated his ability to increase his activity tolerance and ambulation due to improved posture and trunk control.

The PMV allowed his therapists to introduce expiratory muscle strength training (EMST), increasing expiratory strength for breath support for phonation. Additional benefits of EMST include improved secretion management and airway clearance, greater vocal intensity, improved speech intelligibility and increased words per minute. Once Scott was able to use a cap on his trach, inspiratory trainers were introduced.

These interventions contributed to the timeliness of weaning Scott from the ventilator and trach decannulation.

Summary

Understanding the interthoracic connection and utilizing a multidisciplinary team method of treatment for all patients, especially for those with tracheostomy tubes, will contribute to reaching patients' goals and maintaining life time management of their health.

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