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Toolbox for Tracheostomy Issue

In this Issue:

Considerations for tools used for voice, respiratory, and swallowing disorders in patients with tracheostomies

Considerations for the Use of Neuromuscular Electrical Stimulation for Patients with Tracheostomy Tubes

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Abstract

It is well documented that patients with tracheostomies are at a significant risk for dysphagia, often marked by increased frequencies of airway invasion (i.e., penetration and/or aspiration). This may be due to alterations in sensory function, motor function, or mechanical insufficiency, any of which may be contributors to the multi-factorial manifestation of dysphagia in these patients. Dysphagia in these patients contributes to delays in weaning and decannulation, as well as overall functional outcomes, highlighting the importance of identifying and then managing or rehabilitating swallow function. Early and targeted rehabilitation of swallowing function is recommended whenever possible, and various approaches may be functionally useful. An understudied and underutilized modality for targeting swallow function in patients with tracheostomy and dysphagia may be neuromuscular electrical stimulation. Here, we discuss the applications of neuromuscular electrical stimulation in patients with tracheostomies and dysphagia, including considerations of the factors contributing to dysphagia, such as underlying illness and physiological impairment, as well as tracheostomy-specific factors such as cuff status and speaking valve use.

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Introduction

Dysphagia is a known risk factor in patients with a tracheostomy (Skoretz et al., 2020) and is recognized as negatively contributing to several aspects of patient recovery, including weaning, decannulation, and general functional outcomes (Gallice et al., 2024; Wallace & McGrath, 2021). Though not every patient with a tracheostomy in place may have dysphagia (Skoretz et al., 2020), many patients with a tracheostomy tube placed also have underlying diseases, disorders, injuries, or other co-morbidities causing dysphagia that contributed to the need for tracheostomy placement (Mills et al., 2023; Skoretz et al., 2020). Early assessment and intervention for dysphagia are recommended to facilitate positive outcomes, including decannulation (Romero et al., 2010; Wallace & McGrath, 2021). However, the evidence surrounding interventions designed to directly address the sensorimotor function of an area most likely to be compromised by a tracheostomy, the larynx, is limited. Approaches such as tactile stimulation and pharyngeal electrical stimulation show promise in specific populations (Eskildsen et al., 2024), while other oral-based neuromuscular retraining showed no effect on time to decannulation (Blichfeldt et al., 2025). In addition, it is documented that the care pathway leading to decannulation involving cuff deflation and the use of a speaking valve may have positive effects on swallowing outcomes due to restoration of airflow to the upper aerodigestive tract (Mills et al., 2023). However, this may not target other underlying physiological impairments. This leaves a substantial gap in translatable knowledge of what treatment approaches clinicians may have in their tool belt when approaching a patient with tracheostomy and dysphagia. Another treatment option to consider may be the use of neuromuscular electrical stimulation (NMES).

Sensorimotor Alterations to the Larynx With a Tracheostomy

It is theorized that the presence of a tracheostomy with an inflated cuff contributes to the desensitization of the larynx and upper aerodigestive tract, due to the air being redirected through the tracheostomy tube rather than through the glottis (Ding & Logemann, 2005; Shaker et al., 1995). A recent study by Marvin and Thibeault (2021) highlighted that in patients with tracheostomy who aspirated, 81% aspirated silently, adding support to the theory of reduced sensation in the airway with a tracheostomy. This is similar in theory to findings that restoring airflow through the glottis via a speaking valve, where appropriate, allows for the sensorimotor interplay between an adducted glottis and the buildup of subglottal pressure to resume (Gross et al., 2003, 2006; Skoretz et al., 2020) and significantly reduces the odds of aspiration (O'Connor et al., 2019). While approaches have documented positives both in the lab and at the

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bedside, it is critical to factor in patient individuality in the rehabilitation of dysphagia with a tracheostomy (Brodsky et al., 2020; Marvin & Thibeault, 2021). As another example from Marvin and Thibeault (2021), 97% of their patient sample had their cuff deflated, yet still saw substantial rates of silent aspiration. As such, while in many patients' circumstances cuff deflation may improve aspects of swallow function, like aspiration status (Davis et al., 2002; Ding & Logemann, 2005), we must consider the underlying etiology leading to the tracheostomy placement and the subsequent physiological impairment of swallowing because of this etiology.

Individualistic considerations must also be taken in terms of motor impairment with a tracheostomy. There is conflicting evidence regarding whether the presence of a tracheostomy itself affects swallowing biomechanics, such as the hyolaryngeal movement. Suiter et al. (2003) found that a deflated cuff resulted in greater hyoid bone displacement, and Ding & Logemann (2005) found reduced laryngeal elevation with an inflated cuff. Jung et al. (2012) also found that decannulation of a tracheostomy tube resulted in greater hyolaryngeal excursion. In contrast, Terk et al. (2007) found no effect of tracheostomy presence on hyolaryngeal movement. Therefore, it is important to consider the individual patient’s anatomy (i.e., “size of their system”, post-surgical changes, etc.) in relation to the tracheostomy and then to implement instrumental assessment when it is thought that the tracheostomy is impeding hyolaryngeal movement (Van Der Kruis et al., 2011).

Of greater rehabilitation-specific concern are changes and alterations in muscular and motor function due to the presence of a tracheostomy (i.e., disuse), the underlying impairment (i.e., stroke), or both. Patients with tracheostomies are often in critical or intensive care units or wards and are susceptible to muscle weakness and deconditioning (Brodsky et al., 2020; Jolley et al., 2016), which may be attributed to disuse (DeVita & Spierer-Rundback, 1990; Wallace & McGrath, 2021). Critical illness polyneuropathy and myopathy as syndromes affect the sensorimotor function systemically in a large portion of patients in critical or intensive care, including those with tracheostomies (Gutmann & Gutmann, 1999; Zhou et al., 2014) and have been linked to high rates of dysphagia in these critically ill patients (Mirzakhani et al., 2013). It is therefore paramount to consider the combination of the current status of the patient (i.e., prolonged disuse of laryngeal musculature, prolonged NPO status) and underlying factors precipitating the tracheostomy placement (Suiter, 2014), many of which are known to contribute to neuromuscular dysfunction in dysphagia, including stroke and acquired brain injury.

Basis for Neuromuscular Electrical Stimulation for Dysphagia in Patients With a Tracheostomy

Implementing a treatment approach for dysphagia in patients with tracheostomies should be approached based on the individual needs and status of the patient. As an example, a therapy approach such as pharyngeal electrical stimulation may be beneficial in applying sensory electrical stimulation to the pharynx of patients with tracheostomies who were recently weaned from mechanical ventilation or after prolonged disuse of swallowing musculature (Suntrup et al., 2015). Given the data discussed above regarding the impact of sensory input having positive effects on swallowing, it may be that the input of sensory level stimulation in patients who may not be able to tolerate cuff deflation or speaking valve placement may be beneficial. Similarly, Facio-Oral Tract Therapy (FOTT) provides a sensory-based facilitation technique, including to the larynx, useful in patients with tracheostomies who are appropriate for cuff deflation (Eskildsen et al., 2024). While useful for incorporating sensory stimuli, patients with a tracheostomy and dysphagia experiencing disuse atrophy, muscle weakness, or polyneuropathy may require more direct facilitation of motor function.

Protocols for incorporating active laryngeal exercises in patients who can tolerate a deflated cuff but still have aspiration have been proposed, including the Mendelsohn maneuver (Vandenbruaene et al., 2008). However, to our knowledge, no follow-up studies have been implemented specifically incorporating active laryngopharyngeal-based exercises to evaluate improved swallow function. Protocols requiring active exercises are also dependent on the ability of the patient to participate, as well as other factors such as fatigue. It, therefore, may not be possible for the patient to achieve sufficient stimulus to perform the number of swallows to see a benefit in muscular function. An approach that applies to a combined sensorimotor, facilitative, and perturbative approach, such as NMES, may be beneficial for maximizing gains in swallow function in this population.

> *It is vital to understand the underlying biomechanical impairment leading to dysphagia in the patient.*

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NMES as a therapeutic modality to target improved neuromuscular function has been suggested for use in rehabilitative settings for decades (Lake, 1992; Sheffler & Chae, 2007; Ward & Shkuratova, 2002). Ongoing research has contributed to understanding its underlying neuromuscular mechanisms (Doucet et al., 2012), its ability to improve deficits related to motor performance (Maddocks et al., 2013), and its contribution to therapeutic programs for rehabilitation of progressive diseases affecting optimal muscle function (Jones et al., 2016). Generally, NMES is meant to be utilized as a modality that generates muscular contractions, facilitates muscular movement, and is intended to do so in conjunction with muscular contractions (Doucet et al., 2012).

It is therefore vital to understand the underlying biomechanical impairment leading to dysphagia in the patient. It is also imperative to utilize NMES not as a "set it and forget it" dysphagia modality. The key here is to facilitate muscular movement during functional tasks. During active NMES, the patient should be making efforts to swallow. Patients cannot perform functional goal-oriented tasks without actually performing the task (swallowing) and doing so safely, with saliva swallows only.

Electrode Placement and Type

In the context of pharyngeal stage dysphagia in patients with tracheostomies and considering the potential for decreased muscular function and underlying comorbidities with a tracheostomy, such as brain injury or stroke, elevation of the hyolaryngeal complex for biomechanical goals, such as optimal airway protection, is also likely to be affected. Many investigations have explored various electrode placements on the anterior neck to affect hyolaryngeal movement and decrease penetration or aspiration, including on the suprahyoid muscles alone, infrahyoid muscles alone, or in some combination (Diéguez-Pérez & Leirós-Rodríguez, 2020). From the physiological standpoints (generating contractions, facilitating movement, and actively working to move these facilitated muscles), the most appropriate placement of electrodes when performing NMES is over the suprahyoid musculature.

In terms of suprahyoid structure and function, in-depth muscular analysis based on fiber bundle types and concentration indicates that, when functioning together, muscles including the geniohyoid, mylohyoid, and anterior belly of the digastric are designed to move the hyolaryngeal complex superiorly and anteriorly, quickly, and timely (Shaw et al., 2017). When swallowing, a major biomechanical goal that serves as a protective mechanism is hyolaryngeal excursion. Therefore, it makes the most physiological sense that we want to generate contractions of these suprahyoid muscles to facilitate elevation of the hyolaryngeal complex, as this is a function we are trying to improve. The utilization of NMES as a dysphagia treatment modality is unlikely to be beneficial if it is used to stimulate and facilitate the antagonist muscles (infrahyoids) of this pivotal movement.

It could be argued that causing descent of the hyolaryngeal complex may introduce a perturbation effect, whereby patients must overcome the resistance applied during stimulation as a therapeutic approach (Humbert et al., 2015). However, a major point of NMES, aside from generating contractions of a target muscle and facilitating that muscle moving towards a goal-oriented point (i.e., extension of the knee when the quadriceps contract or, more relevant, elevation of the hyolaryngeal complex via the suprahyoids contracting), is the potential for improved muscular strength and hypertrophy (size). It is well recognized that the use of NMES improves strength and size in the muscles being stimulated (Alqurashi et al., 2023). We must therefore carefully consider the muscles (and the goals of these muscles) to which we want to apply these effects. From a physiological standpoint, it makes the most sense to stimulate muscles in a goal-oriented direction that aligns with swallow function (hyolaryngeal excursion) rather than the opposite. Recent studies have shown that when using suprahyoid placement (and appropriate parameters), significant elevation of the hyolaryngeal complex can be achieved (Ogura et al., 2022; Safi & Mohamud, 2021) to facilitate a functional motor pattern of upward and forward movement for swallowing function. Understanding the goals and effects that NMES can have should serve as foundational guidance for clinicians considering its use as a dysphagia treatment modality.

A final consideration when discussing placement may be the electrode type being used over the suprahyoids. It is established in the exercise physiology literature that when implementing NMES, larger electrodes are more comfortable for patients (Flodin et al., 2022). Using an approach to NMES that incorporates larger-sized electrodes spreads out the density of the current over a larger area. While this has been documented to then require a higher intensity of current for muscle contraction, it also reduces how concentrated the current is over the suprahyoids (Flodin et al., 2022). The important

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takeaway here is that this makes NMES more comfortable for the patient because the intensity is spread out over a greater area. This also allows the patient to tolerate more intensity, which may be linked to increased muscle strength beyond certain intensity levels (Glaviano & Saliba, 2016).

Within these points, something that is less clear is how electrode shape may affect things like patient comfort and placement with a tracheostomy. Electrode shape does not appear to affect patient tolerance to simulation (Forrester & Petrofsky, 2004). However, electrode shape should certainly be a point to consider, given the unique shape of the suprahyoid/submandibular space. An example of electrode placement in Figure 1 shows the suprahyoid/submandibular space, and it does not look like an arm or leg. However, much of the research has been conducted on extremities, making it much harder to fit large circular or square electrodes to the neck. This space is small and angular, shaped like a boomerang, and does not have a large surface area to place electrodes. Additionally, while a muscle like the anterior digastric is shaped similarly to muscles like the rectus femoris in the quadriceps (a long, bandlike muscle), other muscles of the neck are quite different in shape, yet still a suprahyoid muscle, like the mylohyoid (triangular, fan-shaped). We are also trying to contract these other muscles; therefore, using a size and shape electrode that works efficiently to reach muscle fibers that are superficial and band-shaped (geniohyoid) but also deep to this muscle and fan-shaped (mylohyoid) is preferable to smaller, less efficiently shaped electrodes that may not cover this area and may cause more discomfort. Consideration must be given to the muscle that is being stimulated and the electrode that is to be used.

Figure 1: Placement example for NMES

Parameters

Skeletal muscle unit firing rates during voluntary contractions tend to occur anywhere between a frequency of 10-50 Hz (Asmussen et al., 2018; Doucet et al., 2012). These factors indicate that NMES in dysphagia treatment should be implemented at the typical firing rate of skeletal motor units and be used in a facilitative manner to induce muscular contractions. Other considerations include the amplitude or intensity of the stimulation, the phase duration of the stimulation, and the duty cycle (how long the stimulation is on/off).

For duty cycle, if a contraction continues for too long without a recovery phase (i.e., if stimulation is provided to a muscle for too long), waste products build up to a level that causes metabolic fatigue and prevent the muscle from using the energy needed to continue contracting (Hunter et al., 2004). In a very practical example, applying stimulation to a muscle for significant amounts of time (i.e., 60 seconds) at frequencies (i.e., 80 Hz) beyond what is necessary for muscles to contract comfortably increases the likelihood of fatigue in a muscle and requires increased recovery time for that muscle. In a patient with a tracheostomy and dysphagia due to neuromuscular impairment, the goal with NMES should be to make the muscle work to improve strength and function, not to try to force it to contract for as long as possible. The duty cycle and stimulation intensity, therefore, must be great enough to apply a load to the muscles, but not too much to fatigue the muscles so that they no longer contract. The purpose here is to achieve and facilitate hyolaryngeal excursion as the primary biomechanical movement. From here, other secondary effects may be observed due to the inherent anatomical connections of other structures and the larynx.

When NMES in dysphagia rehabilitation is implemented at the typical firing rate of skeletal motor units and used in a facilitative manner to induce muscular contractions for a set period that also includes time for muscles to recover, the intervention can be beneficial for patients. These are especially important factors to consider for the tracheostomy patient population who have the added complexity of a tracheostomy tube inserted into the trachea just below the larynx. The amount and intensity of work put through these muscles must be carefully weighed against what the patient can tolerate.

Please see Table 1 for recommendations regarding parameters for suprahyoid NMES use.

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Table 1 Recommended parameters and electrode size/shape considerations for NMES implementation

Parameter	Suggested Use
Pulse Rate / Frequency	30Hz
Amplitude	0 – 100mA
Phase Duration	50 µsec to 250 µsec
Duty Cycle (On-Off time)	5/25, 5/20, 5/15
Electrode Size / Shape	Triangular, > 1 inch

Considerations for Using Perturbation

A consideration is the use of NMES not only as a facilitative modality for improved hyolaryngeal excursion but also to provide a source of perturbation to improve laryngeal vestibule closure. When using suprahyoid electrode placement, perturbation to this mechanism may not be ideal. However, in regard to improving how the airway closes, perturbation may be a good thing.

Limited data are available on timing events of the airway in patients with tracheostomies. However, in the broad dysphagia literature, there are two major contributors reported to airway invasion: issues with hyolaryngeal excursion and time-to-laryngeal vestibule closure (LVC), and they are both closely related (Smaoui et al., 2022). As an example, during swallowing, the onset of hyolaryngeal excursion often precedes the arytenoid elevation and tilting for complete laryngeal vestibule closure (Perlman & Van Daele, 1993; Shaker et al., 1990), which may create a brief internal stretch (opening) of the vestibule. When NMES is actively applied to the suprahyoid muscles, research is establishing that it creates a significant size increase in the laryngeal vestibule (it opens the airway) (Ogura et al., 2022; Safi & Mohamud, 2021). Facilitating this stretch introduces a perturbation effect to the laryngeal vestibule, forcing the patient to close the airway over a greater distance.

The effects of this may be improved with faster closing speed of the laryngeal vestibule (Watts & Dumican, 2018). Because patients must close the airway across a greater distance from this perturbation, they also need to cover that distance in a time frame that still protects the airway. So, in order to do that, they must close the laryngeal vestibule faster. Time-to-laryngeal vestibule closure is one of the primary factors leading to airway invasion, and prolonged timings substantially increase the likelihood of airway invasion. Though hyolaryngeal kinematics or timing events were not measured, suprahyoid NMES using parameters already discussed resulted in significant improvement in penetration and aspiration occurrence (Martindale et al., 2019; Sproson et al., 2018), suggesting improved movement and timing of the hyolaryngeal complex and the airway. Since patients with tracheostomy have been reported to have a high rate of aspiration, and 81% aspirated silently, laryngeal vestibule closure would be a significant consideration in this patient population (Marvin & Thibeault, 2021).

An important caveat is that NMES should be performed without introducing a bolus and with saliva swallows only. Given the discussion regarding the stretching of the laryngeal vestibule when NMES is active, introducing a bolus for the patient to swallow while NMES is active is contraindicated due to increased aspiration and asphyxiation risk. Safi and Muhamud's (2021) findings clearly suggest there is a heightened risk of aspiration when actively swallowing a bolus with stimulation on.

Application of NMES in the Patient With a Tracheostomy

To summarize the most salient points: 1) dysphagia in patients with tracheostomies should be considered alongside underlying comorbidities, 2) NMES may be a useful treatment approach if the underlying dysphagia is associated with laryngeal impairment (hyolaryngeal excursion, airway closure, airway invasion), and 3) factors such as placement and parameters of the stimulation are vital to not just implement but understand. But what other factors should be considered when using this approach in a patient with a tracheostomy?

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Cuff Status

Just like placing a speaking valve, it is paramount to ensure that the use of NMES placed on the suprahyoids is done with the cuff deflated. Earlier discussion highlighted how a deflated cuff contributes to improved hyoid bone movement (Ding & Logemann, 2005; Suiter et al., 2003). As the application of NMES is to facilitate hyolaryngeal excursion, the patient should be able to tolerate cuff deflation during the treatment session, and treatment session lengths can be adapted depending on patient tolerance.

Beyond facilitating maximal hyolaryngeal excursion, it is also a safety precaution to ensure cuff deflation during NMES application to prevent increasing the odds of tracheal or mucosal injury, stenosis, or granulomas. Additionally, creating muscular contractions that maximize hyolaryngeal excursion may cause the cuff to shift and potentially impinge on the airway or the esophagus, reducing esophageal motility or causing reflux.

In patients who cannot tolerate cuff deflation, sensory levels of stimulation may be used when using the same electrode placement. Sensory levels of stimulation have been used in other studies (Eskildsen et al., 2024) directly on the pharyngeal mucosa in patients with tracheostomies, and as such, transcutaneous sensory stimulation may be applied over the suprahyoid area. This may still provide at least sensory level stimulation to the anterior neck, suprahyoid musculature, and larynx, and has been shown to be effective at reducing aspiration in stroke patients without tracheostomies (Gallas et al., 2010).

Tracheostomy Status and Type

Final considerations are the status of the tracheostomy and the tubing itself. The application of NMES on or near an open wound is contraindicated. Therefore, starting at NMES as an immediate treatment for a new tracheotomy is not advised. In addition, initiating NMES too quickly after tracheostomy placement may cause increases in movement, irritation, and edema around the tracheal housing. The timeframe from post-tracheostomy placement to appropriate use of NMES is variable, but the patient should not have any active wounds or bleeding. Additional types of tracheostomy tubes and cuffs should also be considered. As an example, a metal tracheostomy tube may be contraindicated for the use of NMES due to the active current being produced and passed by the stimulator. Foam cuffs would also be contraindicated, as they cannot be deflated.

Conclusion

NMES, when applied with physiologically appropriate placement and parameters, may be a viable rehabilitative approach to patients with tracheostomies. Specifically, where patients experience dysphagia related to impaired hyolaryngeal movement or airway closure, the use of suprahyoid NMES with functional exercise (e.g., swallowing during stimulation) should be considered as a treatment approach. Sensory level stimulation may also be an alternative approach. Patient and tracheostomy-centered factors must be accounted for, including cuff deflation tolerance, speaking valve use, and tracheostomy type.

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