How to optimize communication and ventilation with one-way (speaking) valves

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Neil worked most recently at a teaching hospital with trauma and burn intensive care units and spent his career treating patients with multiple system, brain and orthopaedic injuries as well as those at risk for multiple system organ failure. His areas of interest and experience include facial crush injuries, gunshot or stab wounds to the head and/or neck, facial burns, inhalation injuries as well as traumatic brain injuries. He worked as a collaborative team member with trauma surgeons, pulmonary intensivists, ENT surgeons and hospitalists to facilitate best practice for optimal patient outcomes. Prior to this, Neil worked at the National Heart and Lung Hospital in London helping to establish an on-site Speech and Language Therapy service and develop policies.

Communication – in its basic sense, the exchange of ideas or information between two or more people – is vital to the human existence. Communication provides control and agency over our environment as well as allows the expression of wants and needs. At its core, communication conveys a message. Effective, successful communication should also contain feedback and feedforward between the partners in a dyad or a person in a group, as well as metalinguistic and non-verbal aspects, including eye contact, facial expression, gestures, tone, or intonation. Written communication evokes memories, imagery or feelings. Without communication there would be no Keats or Shakespeare, no Koran or Torah, no status updates on social media.

Communication is so important that the vision statement of the American Speech-Language Hearing Association (ASHA) is "making effective communication, a human right, accessible and achievable for all"[1]. Likewise, the mission statement of the Royal College of Speech Language Therapists (RCSLT, UK) is "to create better lives for people with communication... needs"[2]. The vision of the Association of Speech Language Pathologists Malta (ASLP) is "to raise awareness for individuals with communication... difficulties to ensure optimum and timely care"[3]. Clearly, based on the vision and mission statements of these international organizations specializing in communication disorders and their rehabilitation, which set industry standards for best practice, successful and effective communication affords us meaning and purpose and ultimately impacts our quality of life.

However one chooses to define communication, primary to most people would be the ability to phonate or speak as critical and essential to the definition. The vocal cords function when subglottal air pressure builds, causing the vocal cords to open. As the subglottal air pressure equalizes to baseline, atmospheric pressure, the vocal cords close. The fine tuning of this opening and closing, as well as the vibration of the vocal cords, gives humans voice.

tracheostomy, either with or without mechanical ventilation, on effective, successful communication. The presence of a tracheostomy tube means the individual's upper airway is bypassed; thus, there is no "normal" voicing produced as there is no air flow past the vocal cords (see Figure 1). In many cases, especially in the acute-care stage, the individual is also mechanically ventilated as well as sedated; therefore, pragmatics, paralinguistics and social aspects of communication are impacted.

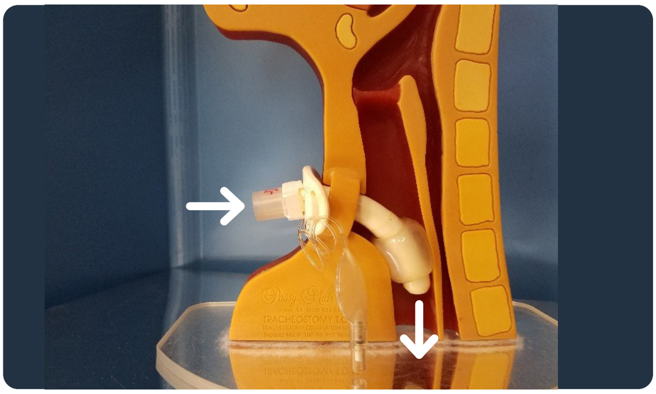


Figure 1 shows the upper airway and trachea (via Tracheostomy Teaching Observation Model, Passy-Muir, Inc. Irvine, CA, USA) with an inflated cuffed tracheostomy. Air (white arrows) passes through the tracheostomy and into the lungs. The presence of an inflated cuff prevents air passing up and through the vocal cords and therefore prevents audible speech.

The lack of ability to communicate and interact with staff and family can give way to feelings of frustration and detachment. In a seminal article on the effects of tracheostomy on an individual's experience, Bergbom-Engberg and Haljamae[4] found that in a retrospective interview (after greater than 2 months) with patients who had been hospitalized and had been respirator-treated and could remember the treatment, 47% felt anxiety or fear during the treatment. Inability to talk and communicate with caregivers was the dominating reason. As long as 4 years after treatment, 90% recalled the situation as unpleasant and stress-evoking.

Similarly, Leder[5] writes that loss of verbal communication is the most disruptive change for tracheostomized patients, owing in large part to the inability to communicate with caregivers about medical care.

Options exist for individuals with a tracheostomy to establish and augment communication with family, staff and community, from basic to high-tech, and may include reliable yes-no responses, communication (icon or letter) boards, white boards or clipboards with paper for writing, mobile or tablet apps, text-to-speech apps, electrolarynx, or high-end speech-generating devices which may include voice or speech banking (in instances of progressive, degenerative disease).

In the acute stage of tracheostomy, either with or without mechanical ventilation, the options are likely more low-tech, and thus, not as effective or efficient. Low-tech options often do not allow or re-establish appropriate, conversational pragmatics. The individual with a tracheostomy is often left to answer only yes-no questions, sometimes with no time for response, or the staff or family speak for the individual. Even worse, the staff or family speak over the individual's attempt to communicate a response. Many wants and needs are predicted. In the acute stage, the presence of a tracheostomy may be dehumanizing and isolating[4, 5].

ONE-WAY VALVES:

A one-way valve which can be used with an individual who is spontaneously breathing, or applied in-line with an individual who requires ventilator support, is another option to enhance communication with caregivers and family. These valves are colloquially known as 'speaking valves' (Figure 2 and 3) since they redirect airflow during exhalation through the upper airway past the vocal cords, allowing subglottal air pressure to build, and therefore, opening and closing the vocal cords in a more normal pattern, providing voicing[6-8]. The valve is beneficial to the individual's quality of life and independence by improving communication with caregivers allowing expression of wants and needs, and increasing the individual's interaction, socialization and engagement[5, 9, 10].

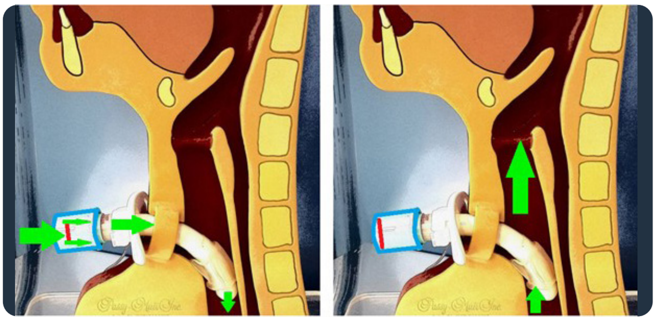


Figure 2 demonstrates the path of airflow (green arrows) for inspiration (left picture) and on expiration (right picture) note how air passes through the speaking valve and passes down into the airway the valve then closes and air is unable to pass out of the tracheostomy and is directed upwards through the vocal cords and out the upper airway.

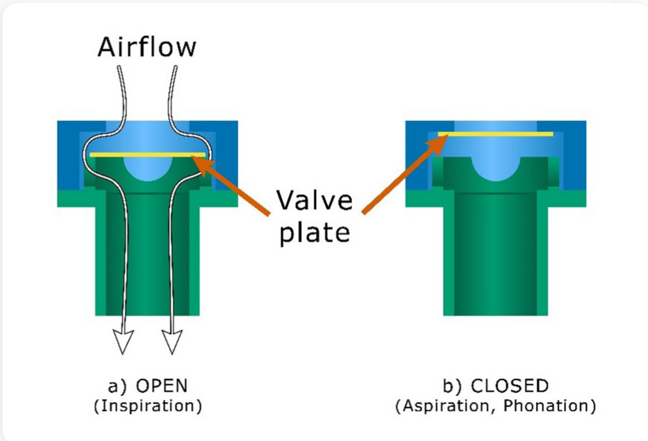


Figure 3 is a diagram of the physical mechanism of a diaphragm / flapper valve and how the valve plate moves, in the open position air passes through the valve and in the closed position air is unable to pass through the valve and air is directed through the upper airway and vocal cords enabling phonation.

(Illustration with thanks to Zak Hughes.)

Many options exist for one-way valves, designed for placement at hub of tracheostomy tube or in-line with either spontaneously breathing or mechanically ventilated individuals. There are two main styles: a diaphragm / flapper valve (e.g. Passy Muir Valve (PMV) (Figure 4), or (Rusch, Figure 5), or a ball valve (e.g. Shikani). The diaphragm / flapper style may be further divided into two sub-groups: (1) a bias-open design, wherein the diaphragm is open at all times and only closes on exhalation (i.e. Kistner, Montgomery, Olypmpic, Rusch), and (2) a bias-closed design, wherein the diaphragm is closed at all times and inspiratory effort is needed to open the valve's diaphragm as in Figure 5[5].

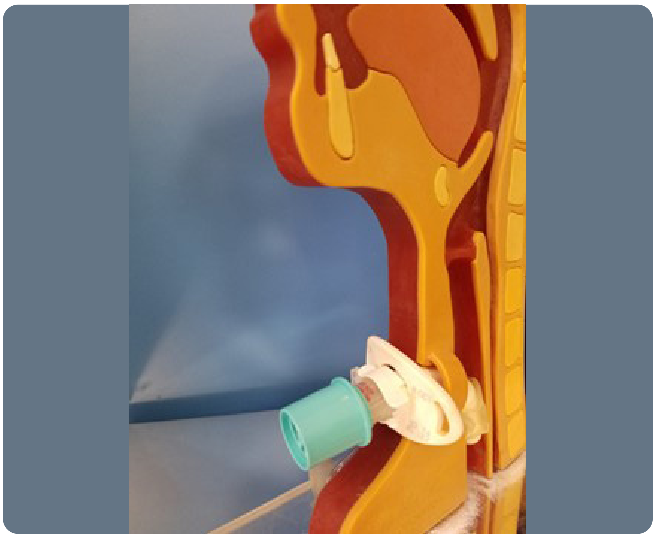


Figure 4 is an example of a bias-closed diaphragm / flapper valve (PMV® 007, Passy-Muir, Inc. Irvine, CA, USA) with Tracheostomy Teaching Observation Model (Passy-Muir, Inc. Irvine, CA, USA).

Figure 5 is an example of a bias-open diaphragm / flapper valve (Rusch 00076, AB Fogless International, Hasselby, Germany) with Tracheostomy Teaching Observation Model (Passy-Muir, Inc. Irvine, CA, USA).

In a hallmark study, Leder[5] found the Kistner valve had significantly greater resistance than the PMV, Montgomery or Olympic valves; it also had the worst frequency distribution or range, as well as 100% air leak during speech production. The Olympic valve demonstrated a loud click during speech, 98%. The Olympic and Montgomery valves each had negligible hiss or air leak at 8%. The Montgomery valve had a 'soft click' with speech, 34%. However, PMV had negligible click during speech, 6%. The PMV demonstrated the highest speech quality and frequency distribution or range, it was also judged the best for listeners and subjects in terms of sound and quality of voicing. This is attributed to the PMV establishes normal physiology of the closed respiratory system[11].

The bias-closed design of the PMV affords many benefits to the individual with a tracheostomy, more than simply voicing and sound quality. It also provides natural positive end expiratory pressure (PEEP), a sense of taste and smell as the upper airway is engaged, aids in the re-establishment of sub-glottal air pressure for improved swallowing safety, and the ability for a stronger cough[12]. Additionally, owing to the PMV's bias-closed design, it is the only diaphragm valve which can be placed during mechanical ventilation[8]. Due to the bias-closed design, there is a complete seal with no air leak into the tracheostomy or ventilatory tubing, thus the full volume of the ventilator setting will be delivered[6, 13].

With team approval of ICU intensivist, Pulmonologist, physician, medical team or upon physician order (USA), a speech-language pathologist (SLP) may proceed with one-way valve trials, whether the individual is spontaneously breathing or requiring ventilator support. The medical team or ventilation team, and respiratory physiotherapist or respiratory therapist need to be aware of one-way valve requirements for trial application when ventilator support is required. Namely: (1) cuff deflation, and (2) changes to the ventilator and constant monitoring to ensure the ventilation team-approved or -suggested volumes or the physician-prescribed volumes are maintained during the trial.

Whichever one-way valve is selected or is used by a particular facility, to trial with the individual, the following are considerations and screening criteria for placement of one-way valves:

Inclusion criteria:

1. Individual is awake and alert[12]; exhibits basic/concrete level cognition including reliable, appropriate yes-no response and follows commands
2. Individual is attempting to communicate[12], either mouthing or articulating words or phrases to staff and family
3. Individual presents with tracheostomy placed greater than 48 hours
4. Individual demonstrates resting respiratory rate less than 30
5. Individual tolerates cuff deflation[12]
6. Individual demonstrates stable medical and pulmonary status[12]; attending physician and team are in agreement with trial and use of one-way valve and approve of and / or order consultation for trial application (in most facilities, this is done by SLP or Speech-Language Therapist (SLT))
7. Individual tolerates ideal positioning for respiratory mechanics to adequately achieve successful and effective one-way valve application trial. In the acute care phase, this position is typically considered to be seated upright at 90 degrees; if the patient cannot tolerate increased head of bed to 90 degrees, ideal positioning would be head of bed greater than 45 degrees[6, 7, 14]

Exclusion criteria:

1. Individual demonstrates significant signs of distress or anxiety
2. Individual presents with foam-filled cuff[12]
3. Individual presents with copious, thick secretions[12], such that cuff may not be safely deflated
4. Individual demonstrates resting respiratory rate greater than 30
5. Individual is neither alert or awake nor follows commands consistently
6. Individual presents with pre-existing, known sub-glottal stenosis or upper airway obstruction or vocal cord paralysis[15]
7. Patient is status post total laryngectomy[6]
8. Individual presents with hemodynamic instability due to complex, critical illness
9. Individual demonstrates severely compromised or impaired lung compliance or elasticity[12]

APPLICATION OF ONE-WAY VALVE FOR INDIVIDUAL WHO IS SPONTANEOUSLY BREATHING / NON-VENTILATED

The Individual is instructed on purpose and rationale of trial, as well as expectations, how one-way valve changes breathing patterns. A pre-agreed hand gesture or signal for one-way valve to be removed if distress or discomfort occurs should be established. The individual should be able to understand need for removal of one-way valve and be able to demonstrate the agreed-upon gesture or signal to cease trial.

SLP should identify and know the baseline or resting cardio-respiratory parameters of the individual: the respiratory rate, the heart rate and the oxygen saturations as well as the individual's resting work of breathing, secretions, need for suctioning or secretions clearance and overall demeanor (i.e. is the individual calm, distressed, anxious, restless, etc.).

Step 1: Cuff Deflation

If the individual has a cuffed tracheostomy tube, the cuff should be deflated slowly over a 3 to 5-minute period of time[6, 12, 15] to allow the individual to acclimate to the feeling of air past the vocal cords and into the upper airway. SLP should monitor the patient as per Table 1.

Table 1: Monitored parameters and action to be taken in the event of patient deterioration

Monitor	Respiratory rate	Heart rate	Oxygen saturations	Work of breathing
Observation	Increase ↑ or decrease ↓ by 25% compared to baseline		≤ 90%	Signs of anxiety and distress
Step 1 action	Inflate the cuff and monitor until back to baseline, if the patient does not settle alert the medical team			
Step 2 action	Remove finger and evaluate why the patient did not tolerate finger occlusion			
Step 3 action	Remove the one-way valve and allow the patient to return to their baseline			

Moreover, upon initial cuff deflation, if the individual has secretions at rest that are sitting on the inflated cuff, these secretions may flow down into the trachea past the tracheostomy tube and require suctioning. In some disease processes, the pulmonary secretions are so great that merely deflating the cuff may cause copious secretions which require immediate suctioning and warrant re-inflation of the cuff to baseline.

If the individual tolerates initial cuff deflation with stable heart rate and respiratory rate as well as maintaining oxygen saturation, the SLP may assess the individual's ability to produce leak phonation. The SLP may prompt the individual to phonate a vowel: /a/. If the individual tolerates and is able to produce an audible /a/, this may be followed by requesting the individual to say his or her name or phonating a sequence of syllables or short phrase (i.e. 'count to five'). Whilst the individual is attempting to phonate at basic levels, the SLP should monitor closely the respiratory rate, the heart rate and the oxygen saturations throughout: an increase of greater than 25% of baseline RR or HR should prompt re-inflation of the cuff to baseline. Likewise, an oxygen saturation of less than 90% or visible, obvious changes to the work of breathing or change in baseline demeanor (i.e. calm to anxious) or an increase in audible, wet, coarse secretions should prompt re-inflation of the cuff to baseline. A rest period of 5 to 10 minutes may be considered, as well as tracheal suctioning and/or oral suctioning if the individual demonstrated increased secretions or increased audible breath sounds during this rest period. If the individual demonstrates a return to baseline respiratory rate, heart rate and oxygen saturation, the SLP may attempt additional leak phonation again in the same session or trial to allow the individual an opportunity to acclimate to the feeling of air past the vocal cords and into the upper airway.

Step 2: Finger Occlusion Trial

The individual may be too weak or not have the breath support to produce leak phonation. The SLP may assess the individual's ability to produce leak phonation and assess upper airway patency further via finger occlusion trials. The SLP, using sterile procedure and gloves, should place finger over exposed end of inner cannula or single-cannula tracheostomy.

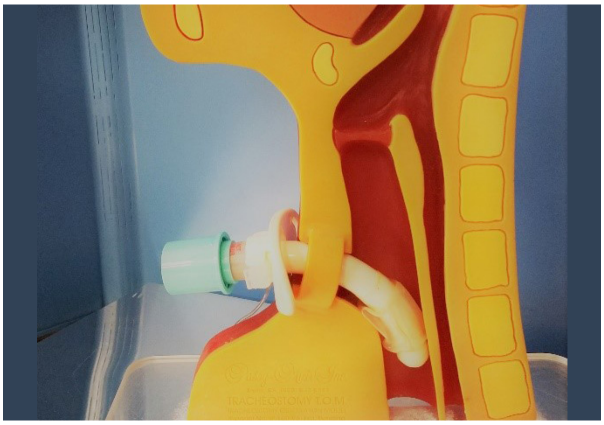
The SLP shall carry out the same procedure as described in Step 1 (initial cuff deflation). If the individual does not tolerate finger occlusion trial, a rest period of 5 to 10 minutes may be considered, as well as tracheal suctioning and/or oral suctioning if the individual demonstrated increased secretions or increased audible breath sounds during this rest period. If the individual demonstrates a return to baseline respiratory rate, heart rate and oxygen saturation, the SLP may attempt additional finger occlusion again in the same session or trial to allow the individual an opportunity to acclimate to the feeling of air past the vocal cords and into the upper airway.

If the individual does not tolerate cuff deflation, with neither air exhaled through the mouth or nose nor leak phonation, or if the individual does not produce minimal leak phonation or demonstrate exhalation through the upper airway with finger occlusion trial, the SLP should proceed with caution. Initial troubleshooting idea is the individual is weak and demonstrating debility and deconditioning, or disuse atrophy[6, 8, 16], associated with prolonged ventilator support, or complex, critical and acute comorbidities, or chronic illness or diagnosis. In his formative work, Sasaki[17] found long-term tracheostomy, which bypasses the upper airway, leads to decreases in glottic closure response, in part, due to disruptions to sub-glottic air pressure which, in turn, impacts adduction and abduction of the vocal cords[18, 19]. Sasaki[20] later found that chronic tracheostomy can result in laryngeal incoordination: adductor reflex is longer in duration and reveals weaker closure of the vocal cords. As well, abduction of the vocal cords ceases when an individual is ventilated and the upper airway is bypassed. Abductor activity may be restored with increased resistance; however, the longer the time the upper airway is bypassed, the more challenging to restore the abductor function[20]. The smooth muscles of the larynx (both intrinsic and extrinsic) have discrete movements to provide abduction and adduction for respiration, swallow safety, and phonation. These muscles also lengthen and shorten, as well as alter the tension (fatten and thin) of the vocal cords for phonation. Cessation of their function can occur easily and quickly leading to weakness, especially without adequate sub-glottic air pressure to drive their specific movements. If the individual has chronic comorbidities or a neuromuscular disease, he or she may require an extended treatment plan, or merely time, to restore the functions of these muscles (e.g. strength) to adapt to cuff deflation and tolerate one-way valve placement with effective phonation. Then additional time to build duration of one-way valve placement for a few minutes to communicate with family, careers or staff.

The second troubleshooting idea is the tracheostomy tube may be too large for the tracheal lumen to allow airflow around the tube and up past the vocal cords into the upper airway. The individual may require a smaller tracheostomy tube (downsized by facility policy) or, if possible, an uncuffed tracheostomy tube[12]. Each of these options would allow the maximal amount of airflow around the tracheostomy tube and up past the vocal cords.

A more serious concern for airway patency is the individual may have an undiagnosed upper airway obstruction or swelling which precludes safe and successful cuff deflation or one-way valve application. If an upper airway obstruction is suspected, depending on the facility and services available, direct visualization of the airway and upper airway should be considered for differential diagnosis via fiberoptic endoscopic evaluation of swallowing (FEES) by SLP, Otolaryngology consult with direct laryngoscopy, or, at the minimum, a CT of the neck prior to proceeding with trials and successful application of a one-way valve. Diagnoses which may lead to suspicion of upper airway obstruction or laryngeal edema include: prolonged intubation prior to tracheostomy, prolonged ventilator dependence (three to six months), tracheal injury, stab or gunshot wounds to the face or neck, anterior-approach cervical spine surgery, facial crush injury, complex, displaced mandibular fractures or inhalation and burn injury.

Step 3: One way valve application



Once the individual tolerates cuff deflation and demonstrates leak phonation, the SLP may proceed with one-way valve application. The one-way valve is placed on hub of trach (portion of inner cannula or outer cannula on a single cannula tracheostomy that is visible). The SLP should monitor closely as per Table 1.

Initially the individual should be instructed to breathe and acclimate to the sensation of air flow past the vocal cords.

The SLP should be constantly watching for any lasting change to respiratory rate, heart rate or oxygen saturations; momentary increase or decrease is acceptable, as long as the individual is able to return to baseline or resting cardio-respiratory parameters with minimal prompting. If the cardio-respiratory parameters do not return to baseline, or the individual indicates discomfort or distress, the one-way valve should be removed, and baseline cardio-respiratory parameters allowed to re-establish prior to additional attempt(s) in the same session or trial.

If the individual only tolerates the one-way valve for 5 minutes the first attempt, this is acceptable. The goal is to increase the time the one-way valve is tolerated and opportunity to increase spontaneous breathing and communication with caregivers and family. Achieving the goal of tolerating the one-way valve throughout a day may take time. Often the goal might be for the individual to tolerate the one-way valve for 30 to 60 minutes at a time, with removal by the registered nurse, SLP, respiratory therapist or physician, and rest period of 60 minutes, several times throughout the day when family is present, to increase communication and interaction. The SLP will establish the maximum wearing time (schedule) and required level of supervision with the valve; the SLP should communicate this information to the care team to increase communication and interaction as well as to maximize benefits of valve for weaning.

When possible, and if medically feasible, the individual, a family member or carer may also be trained to don and doff the one-way valve to increase the opportunity for self-directed care and independence with communication with family and staff. This goal is intermediate or longer-term in treatment after establishing initial tolerance for the one-way valve with effective voicing and spontaneous cough or airway clearance. Moreover, this goal may be added in treatment once the individual tolerates the one-way valve for an extended period of time 60 to 90 minutes.

APPLICATION OF ONE-WAY VALVE FOR INDIVIDUAL WHO IS MECHANICALLY VENTILATED:

Step 1: Initial cuff deflation

As the cuff is deflated initially while on ventilator support, there will be an air leak into the upper airway[12]. Ventilator adjustments will be needed to account for this air escape. The SLP should deflate the cuff slowly over 3 to 5-minute period to allow the individual to acclimate to the change in respiration[12], as well as sensation of minimal air flow past the vocal cords and into the upper airway. Immediately after initial cuff deflation, the individual may require suctioning: either orally, or tracheally if the cough is weak, non-productive, or if the individual presents with diaphragmatic injury or impairment. Mechanical insufflation-exsufflation (MI-E) may need to be instigated to further assist secretion movement and improve suction efficacy. Additionally, the individual will likely need to have tidal volumes increased to account for decreased peak inspiratory pressure (PIP) due to cuff deflation and air leak into upper airway.

Follow the above guidelines and monitoring for cuff deflation. Once the individual who requires mechanical ventilation tolerates cuff deflation without significant changes to baseline or resting cardio-respiratory parameters or copious secretions which require tracheal suctioning, the SLP may trial one-way valve following the above guidelines. Again, the individual will likely need to have tidal volumes increased to account for decreased PIP due to cuff deflation and air leak into upper airway[12]. As the one-way valve promotes natural PEEP via recruitment of the intercostals to expand the rib cage, the PEEP setting on the ventilator may also need to monitored and adjusted[12].

Step 2: Insertion of a one way speaking valve into the ventilator circuit

The one-way valve should be placed as close as possible to the hub of the tracheostomy tube. This is usually done with the use of a 15 x 22 stepped adaptor (See Figures 6 and 7). The one-way valve may also be placed further down-line to swivel tubing or to a closed suction catheter to allow for inline suctioning whilst the one-way valve is in place. This style of placement is accomplished with the use of a 15 x 22 stepped adaptor and wide-mouth, flexible, non-disposable rubber tubing [12].

Figure 6 shows an inline speaking valve (PMV® 007, Passy-Muir, Inc. Irvine, CA, USA). The valve is connected to a 15mm catheter mount then to a 22F-15M connector and then to a ventilator circuit, the valve may be connected directly to the 22mm flexible ventilator tubing. This set up is only suitable if the care team is used to adding an exhalation valve or intentional leak into the circuit for when the patient is not using the speaking valve.

(Picture thanks to Debbie Field, Royal Brompton Hospital, London, UK).

Figure 7 shows an inline speaking valve (PMV® 007, Passy-Muir, Inc. Irvine, CA, USA). The valve is connected to a 15mm catheter mount then to a 22F-15M connector and then to an extendable piece of tubing which will attach to a ventilator exhalation valve or in this picture an intentional leak. This set up is ideal if the care team is not used to changing the ventilator set up and ensures removal of exhaled gases once the speaking valve is disconnected.

CONCLUSION

Communication is a vital component to our lives and affords us control and independence [10]. A tracheostomy allows improved comfort and management of prolonged ventilator support, including decreasing work of breathing and respiratory load [20]. However, presence of a tracheostomy clearly limits communication and expression of an individual's basic wants and needs. Impaired communication due to a tracheostomy may lead to feelings of detachment, isolation, frustration and fear as well as negatively affecting medical decision-making and social interactions [4, 9-11, 21]. This guideline reviewed the use of one-way valves to re-establish voicing and communication for the individual with a tracheostomy, either spontaneously breathing or requiring mechanical ventilation, to maximize independence and increase communicative effectiveness for improved participation in healthcare, psycho-social well-being and overall quality of life [5, 9, 10].

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