Case Report

Glossopharyngeal and Neck Accessory Muscle Breathing in a Young Adult With C2 Complete Tetraplegia Resulting in Ventilator Dependency

Background and Purpose. This case report describes the use of glossopharyngeal breathing (GPB) and neck accessory muscle breathing (NAMB) in the treatment of an individual who was dependent on a ventilator secondary to a spinal cord injury. **Case Description.** The patient was a 19-year-old man with C2 complete tetraplegia. He received a 5-week inpatient program of GPB training 3 to 4 times per week. A 4-week NAMB training program followed. **Outcome.** Following GPB training, forced vital capacity increased 35-fold, time off the ventilator improved from 0 to 30 minutes, and a nonfunctional cough became a weak functional cough. After NAMB training, the patient was able to be off the ventilator for 2 minutes. **Discussion.** Increased ventilatory capability has the potential to affect patients' quality of life by improving cough function and decreasing dependence on a ventilator in the event of accidental disconnection. [Warren VC. Glossopharyngeal and neck accessory muscle breathing in a young adult with C2 complete tetraplegia resulting in ventilator dependency. *Phys Ther*. 2002;82:590–600.]

Key Words: *Emergency breathing techniques, Glossopharyngeal breathing, Neck accessory muscle breathing.*

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The number of people living today with spinal cord injuries who are dependent on a ventilator has increased due to improved intensive medical support.[1–3] One of the greatest fears of people who are dependent on ventilators is becoming accidentally disconnected from the ventilator.[4] Glossopharyngeal breathing (GPB) and neck accessory muscle breathing (NAMB) are 2 alternative breathing techniques that these people can use in emergencies and to promote respiratory health.[5–8]

Glossopharyngeal breathing involves a series of gulps using the lips, tongue, pharynx, and larynx to pull air into the lungs when the normal inspiratory muscles are not functioning[5] (Fig. 1). Glossopharyngeal breathing consists of cycles of 6 to10 gulps of air followed by exhalation. Exhalation occurs when the glottis opens and the inflated lungs deflate passively due to the elastic recoil of the lungs. In addition, GPB has been recommended to allow an individual to perform a functional cough to clear tracheal secretions, increase the volume of the speaking voice, and maintain chest wall mobility.[9,10]

People with high tetraplegia also can use the neck accessory muscles to breathe in the event of ventilator disconnection. Neck accessory muscle breathing uses muscles such as the sternocleidomastoid and scalenus to aid in respiration (Fig. 2).

Glossopharyngeal breathing is an alternative breathing technique that people who are dependent on ventilators can use in emergencies and to promote respiratory health.

Glossopharyngeal breathing was discovered clinically and first documented in the medical literature by Dail in 1951[11,12] when he observed a patient with poliomyelitis who was dependent on a respirator "gulping air" when he was out of the respirator (iron lung) (Tab. 1). The patient had no movement of his diaphragm, yet was able to increase his vital capacity from 250 cc to 600 cc with the use of GPB. Vital capacity is the measurement of the maximum amount of air that can be exhaled after a maximal inspiration.

Although published reports of GPB programs have been available since the 1950s,[5,6,9–18] no literature describes an individual who is dependent on a ventilator secondary to a spinal cord injury using GPB to breathe off the ventilator to improve cough function or for chest expansion to maintain chest wall mobility. Researchers have reported that people who are dependent on a ventilator as a result of poliomyelitis[5,6,10,11,16,17] and Duchenne muscular dystrophy[15] benefited from learning GPB.

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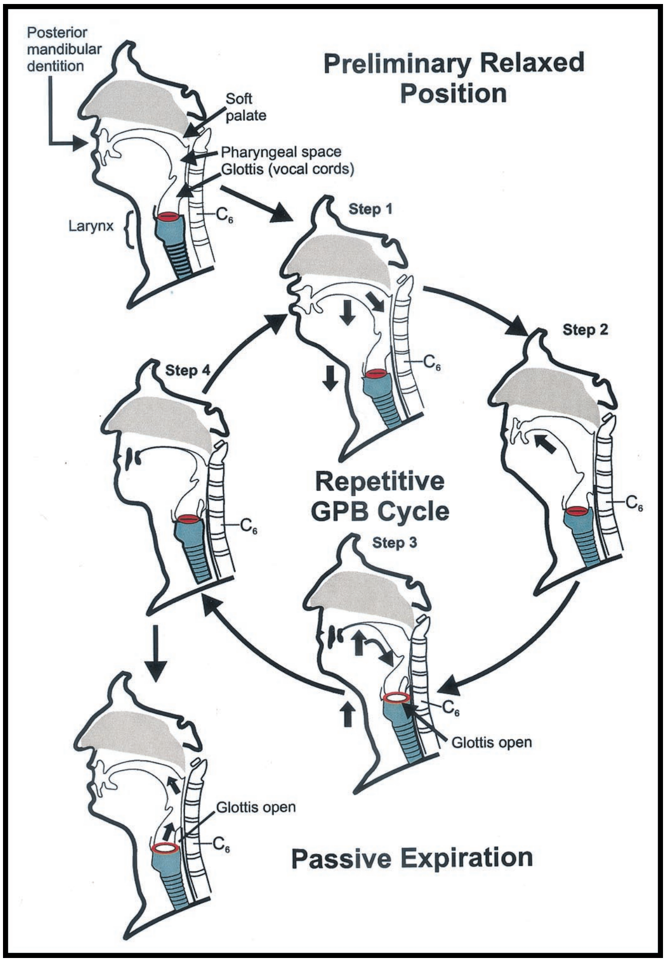

Figure 1.
Anatomy of structures used for glossopharyngeal breathing (GPB). Posterior mandibular dentition is where tongue touches during intervention of GPB. Reprinted with permission from Dail CW, Rogers M, Guess V, Atkins H. *Glossopharyngeal Breathing*. Downey, Calif: Los Amigos Research & Education; 1979:5.

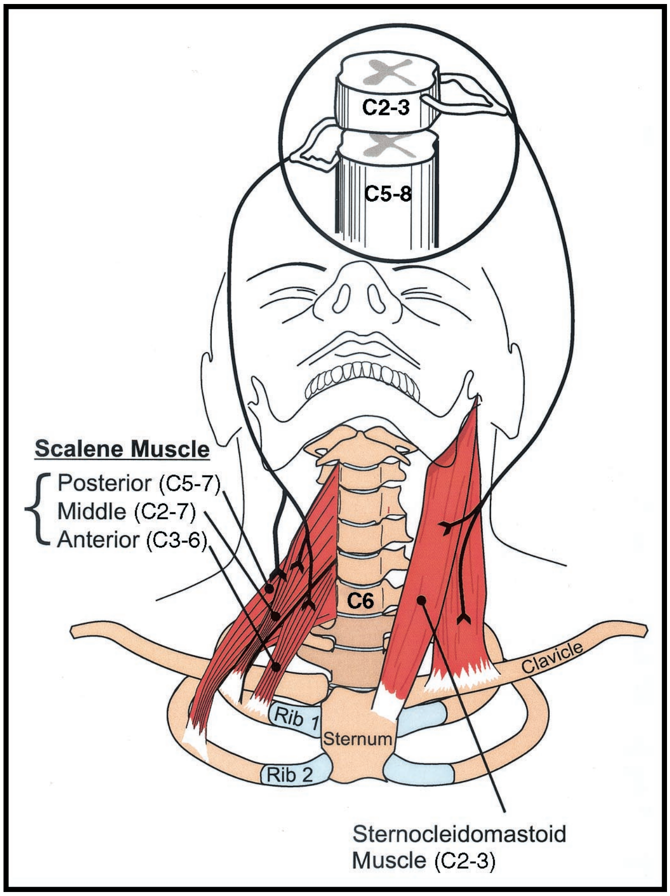

Figure 2.
Muscles innervated for patients with high tetraplegia for use in neck accessory muscle breathing.

Johnson et al[15] presented a case study of a patient with Duchenne muscular dystrophy who was dependent on a ventilator and able to quadruple his vital capacity with GPB. Using GPB, he could count to 25 with a vital capacity of 1,200 cc. He used GPB for up to 2 hours and was able to vocalize. As his disease progressed, however, his vital capacity was reduced to zero, and he was unable to articulate a count of 1.

People who are dependent on a ventilator as the result of a spinal cord injury, however, are different from people with poliomyelitis and Duchenne muscular dystrophy because they usually have both sensory and motor loss of the muscles of respiration. People with poliomyelitis and Duchenne muscular have motor loss only.

Patients with spinal cord injuries who were not on ventilators have been reported to learn GPB. Metcalf[13] published the first study, which involved 23 adults with C4 to T1 complete tetraplegia. Using GPB, the subjects' vital capacity increased to 81% of normal, they were able to perform an effective cough independently, and they maintained pulmonary compliance and thoracic mobility.

Montero et al[14] described 14 people with C5 to C7 complete tetraplegia, aged 15 to 37 years. Using GPB, the subjects added 700 to 1,000 cc of air to their vital capacity, a gain of 28% of normal. Overall, vital capacity increased from 35% to 65% of normal. While performing GPB, they were able to clear secretions from their throats and increase the loudness of their voices.

One report[18] described an individual who was dependent on a ventilator secondary to a spinal cord injury and attempted to learn GPB, but did not succeed. She instead learned to use her neck accessory muscles to breathe when she was off the ventilator. Neck accessory muscle breathing is the only reported emergency breathing technique taught to people who were dependent on a ventilator secondary to a spinal cord injury.[7,8,18] These reports[7,8,18] involved children and one adult.

Table 1.
Previous Studies of Individuals Learning Glossopharyngeal Breathing and Neck Accessory Muscle Breathing[a]

GPB Studies	Sample	GPB Learning Approach	Outcomes
Dail,[11] 1951	Poliomyelitis (5 female, 10 male); inpatients 1–2 y after diagnosis	1. Several patients discovered method without help or suggestion that it was possible 2. Learned from other patients	1. Placed on bed out of respirator (iron lung) 2. Talk much louder and longer on one breath 3. Able to expectorate more easily 4. VC without GPB: $\bar{X}$=314.5 cc, range=10–1,500 cc 5. VC with GPB: $\bar{X}$=1,143 cc, range=300–2,700 cc
Montero et al,[14] 1967	C5-C7 complete tetraplegia (N=14); aged 15–37 y; inpatients 6 mo to 3 y after injury	1. Individual instruction by staff, 30- to 60-min sessions, 3 times/wk 2. Scheduled unsupervised practice sessions for 10 min 2–3 times/d 3. Formal training stopped: a. When patients able to perform cough to clear mucous from upper respiratory tract b. When VC stable for 2 wk	1. Breath holding time increased from 30% to 93% of predicted normal value 2. Maximum breathing capacity increased from 33% to 49% 3. VC increased from 35% to 65% 4. Able to increase VC by 700 to 1,000 cc 5. Maximum expiratory flow increased from 39% to 92% 6. Improved cough effort 7. Time to learn GPB from 1–6 wk
Metcalf,[13] 1966	C4-T1 complete tetraplegia (6 female, 17 male); aged 14–49 y		1. Increased VC to 81% of predicted normal value 2. Prevented tightness of rib cage 3. Maintained pulmonary compliance 4. Independent, effective cough 5. VC without GPB: $\bar{X}$=2,374 cc, range=750–3,800 cc 6. VC with GPB: $\bar{X}$=3,251 cc, range=1,620–5,325 cc
Johnson et al,[15] 1985	Duchenne muscular dystrophy; male outpatient; age 18 y	1. Shown motion picture demonstrating GPB	1. Used GPB while being dressed, transferred, and during short periods of transporting 2. Able to sustain 1–2 h off ventilator using GPB 3. Baseline VC=0, unable to articulate a count of 1; VC with GPB=1,200 cc, able to count to 25 4. Time to learn GPB was several days
Gilgoff et al,[7] 1988	C2 complete tetraplegia (N=8); aged 3 y to 16 y 3 mo; inpatients	1. Strengthening of the neck muscles: manual resistance and activities with oral motor control 2. a. Flexibility of neck and shoulder joint: ROM b. Flexibility: thoracic cage-intermittent positive pressure breathing, manual ROM of chest 3. Elevation of hyoid, upper chest, clavicle a. Demonstrated by therapist b. Imitation while on ventilator c. Feedback: mirrors and verbal direction 4. a. Short periods off ventilator to use neck breathing (ie, suctioning) b. Time off ventilator increased gradually and neck strengthening continued	1. 7 of 8 learned neck breathing technique; one unable to learn, had poor neck strength and only one to require neck support 2. Time disconnected from ventilator ranged from 20 min to 12 h, average=approximately 3.5 h 3. Amount of time to achieve 20 min off ventilator ranged from 18–454 d 4. a. All 8 patients discharged to their homes; average=8 y, range=4–16 y b. 4 out of 8 had episodes of accidental disconnection
Morrison,[8] 1988	C1 complete tetraplegia; male aged 36 y; 8 mo after injury	1. Passive ROM to all extremities and trunk 2. Progressive strengthening of all innervated musculature 3. Mobility training: "sip-n-puff," power wheelchair 4. Biofeedback began once strength of sternocleidomastoid and upper trapezius muscles improved from Trace to Fair	1. After 6 consecutive biofeedback sessions, the patient achieved: a. 35 min off ventilator b. Increase in VC from 50 to 550 cc 2. Breathing session without biofeedback a. 1st session: VC=550 cc; duration=35 min off ventilator b. Next 5 sessions: VC=550 cc; duration=7.5 min; author attributes decrease in time off ventilator to decreased motivation

[a] VC=vital capacity, GPB=glossopharyngeal breathing, NAMB=neck accessory muscle breathing, ROM=range of motion.

Gilgoff et al[7] instructed 7 children with tetraplegia, aged 2 to 16 years, who were dependent on a ventilator to successfully breathe off their ventilators with neck musculature for 20 minutes to 2 hours. Morrison[8] used biofeedback to teach a 30-year-old adult with C1 complete tetraplegia to use his neck accessory muscles to breathe off a ventilator for 35 minutes. When the biofeedback was removed, time off the ventilator decreased to 7.5 minutes.

Donovan and Taylor[18] described an 11-year-old girl with C2 complete tetraplegia who attempted to learn GPB over a 3-month period. The GPB program was discontinued because she developed use of her accessory respiratory muscle, the sternocleidomastoid, which allowed her to breathe off the ventilator for up to 1 hour. She had a tidal volume of 50 to 100 cc and a respiratory rate of 22 breaths per minute. She was also able to speak 3 to 4 words per breath while off the ventilator. Two years later, she was able to breathe off the ventilator for up to 2½ hours as she continued to strengthen her accessory muscles by breathing off the ventilator 2 to 3 times per day.

Many patients today who are dependent on a ventilator as the result of spinal cord injuries might benefit from learning GPB and NAMB. In my opinion, both techniques are important for patients who are dependent on the ventilator to learn because each has advantages and disadvantages. Compared with NAMB, advantages of GPB that I have observed include allowing the patient to develop a larger vital capacity, which can be used to breathe off the ventilator for a longer period of time or to produce a more productive cough to clear tracheal secretions. The disadvantages of GPB include being more difficult to learn and the need to close off the individual's tracheostomy by use of a Passy-Muir valve or cover the opening after accidental disconnection. If the person becomes disconnected above the Passy-Muir valve and the tracheostomy is open, GPB cannot be used because the accumulated air escapes out of the tracheostomy where the ventilator tubing was attached prior to accidental disconnection. If this occurs, the individual must rely on NAMB. In contrast to GPB, NAMB is easy to learn and can be used as an emergency breathing alternative without concern for the site of disconnection. Small volumes of air can be generated to breathe off the ventilator for a more limited time period, however, than with GPB. The heavier the individual, the greater the vital capacity and tidal volume needed to breathe off the ventilator. In my experience, neck accessory muscles cannot generate enough volume of air to allow heavier individuals to breathe off the ventilator for longer than a few weeks. In addition, with NAMB each inhalation is individually transmitted into the lungs, whereas with GPB several gulps of air are accumulated in the mouth before the volume of air is transmitted to the lungs.

Glossopharyngeal breathing has been taught to people using several similar methods. Dail et al[5] learned GPB by studying fluoroscopy, cineflurography, spirography, pneumotachography, and airway pressure measurements and by examining patients and staff who had learned the technique. They reported that, of 100 patients with poliomyelitis, 55 patients were taught GPB by hospital staff, 25 learned with minimal assistance of others, 15 learned from other patients, and 5 learned by themselves without being aware of what they were doing. Patients have been taught GPB by first receiving an explanation of GPB, then watching a movie or videotape of someone performing GPB.[9,15] Patients were trained for 30- to 60-minute sessions 3 to 5 days per week.[9,15]

The purpose of this case report is to describe a 5-week program to teach of an adult male patient with C2 complete tetraplegia to use alternative breathing techniques. The physical therapist and the physical therapist assistant taught the patient both GPB and NAMB.

Case Description

Patient

The patient was a 19-year-old man who was 188 cm (6 ft 2 in) in height and weighed 86.2 kg (190 lb). He had C2 complete tetraplegia secondary to a motor vehicle accident, resulting in ventilator dependency. At the time of his injury, he was attending a local community college for an automotive repair program. He had been in bed for approximately 2½ months due to medical complications at an acute care hospital prior to being admitted to a rehabilitation center as an inpatient.

Examination

The initial examination indicated that the patient was fully dependent on the ventilator; had no diaphragm movement, as indicated by manual palpation; and had a nonfunctional cough.[19] Cough function can be classified as "functional" when a person is able to clear all tracheal secretions independently, "weak functional" when a person is able to clear the throat and small amount of secretions with minimal cough force, or "nonfunctional" when a person is unable to generate any cough force.[19]

The examination also indicated that the patient had 3 mm of chest expansion at the xiphoid process[17,20] and a vital capacity[17,21] of 75 cc when off the ventilator. The vital capacity measurement was taken following the testing procedure of the American Association for Respiratory Care Clinical Practice Guidelines[21] with a handheld Mark 14 Wright respirometer.[*,22,23] Each time I measured the patient's vital capacity, I used the same

* Ferris Medical Ltd, 26 Lea Valley Trading Estate, Angel Rd, Edmonton, London, England NI8 3JD.

method and recorded the highest of the 3 trials. I did not determine the reliability of the measurements. His initial ventilator settings were the following: tidal volume: 800 cc, mode: assist control, rate: 14 breaths per minute, and fraction of inspired oxygen (FIO_2): 30%. His blood gas values were: pH: 7.40, arterial partial pressure of oxygen (PaO_2): 156 mm Hg, partial pressure of carbon dioxide (PCO_2): 35 mm Hg, bicarbonate (HCO_3): 21, oxygen saturation: 99%, and Sigh: 1,200 cc. The patient was placed on room air 22 days after the initial admission. His FIO_2 was decreased to 25% in the morning and to room air (21%) in the later afternoon. The ventilator settings remained unchanged.

To assess whether the muscles of respiration were innervated, manual muscle testing was performed.[20] The patient had 4/5 strength of his upper trapezius, sternocleidomastoid, neck flexor, and neck extensor muscles. At the time he began the GPB and NAMB programs, he was able to sit up daily in a chin-controlled, battery-powered wheelchair with supervision[24] within the hospital ward and contact/steady assistance when operating the wheelchair outside on unlevel terrain.

The power wheelchair involved use of the neck muscles, including the muscles of respiration. For example, the sternocleidomastoid muscle is used to assist with turning and backing up the wheelchair. This activity may have contributed to strengthening his neck accessory muscles. In addition to physical therapy, he practiced using a mouth stick device[25] to assist with turning pages, operating a telephone, and using a computer with his occupational therapist. This patient was able to learn new skills and information quickly, and he appeared to want to learn as much as he could.

Intervention

Based on this patient's examination results (ie, unable to breathe off ventilator, nonfunctional cough, and innervation of neck accessory muscles), intervention related to GPB and NAMB was selected. The patient was instructed in GPB prior to NAMB because, in my experience, it is more difficult to teach GPB once the patient has learned to breathe with neck accessory muscles. When NAMB is taught before GPB, it is difficult to determine whether the patient is increasing inspiratory volume by using structures for GPB or neck accessory muscles.

The patient began to learn GPB once he was able to tolerate breathing with a nonfenestrated cuffless tracheostomy and Passy-Muir valve.† First, the pulmonary physician changed his tracheostomy from a nonfenestrated cuffed tube to a cuffless tube. The cuff was deflated 12

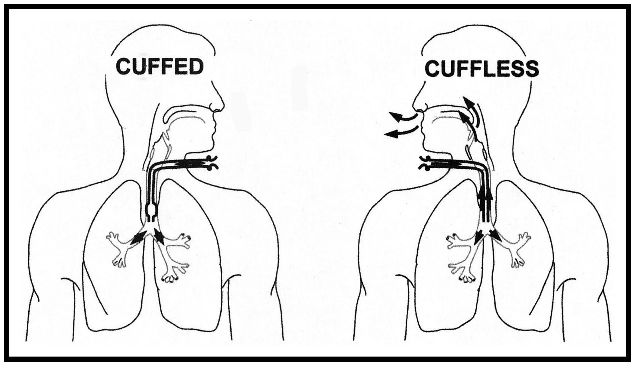

Figure 3.
Airflow with cuffed and cuffless tracheostomy tube. With cuffed tracheostomy tube, inhaled air travels through nonfenestrated tracheostomy tube into the lungs, exhaled air travels only out of nonfenestrated tracheostomy tube, and patient is unable to vocalize. With cuffless tracheostomy tube, inhaled air travels through nonfenestrated tracheostomy tube into the lungs; exhaled air travels around tracheostomy tube, passes over the vocal cords, and exits from nose and mouth; and patient is able to vocalize.

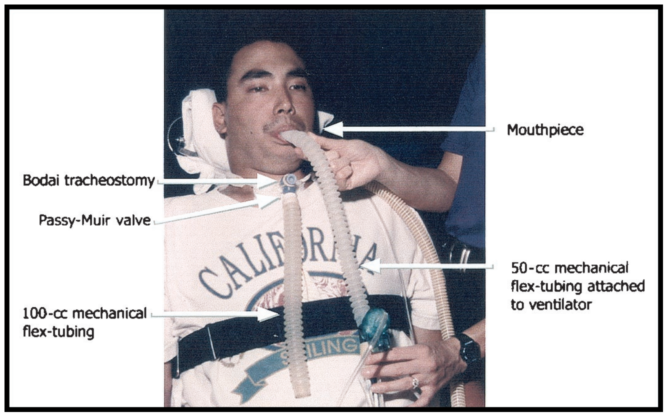

Figure 4.
Setup for breathing with mouth positive air in preparation for learning glossopharyngeal breathing.

days after admission and was changed to a cuffless tracheostomy 4 days later. The ventilator setting remained the same as it was initially, except the Sigh increased from 1,100 cc at initial cuff deflation to 1,200 cc with cuffless tracheostomy (Fig. 3).

A cuffed tracheostomy consists of a balloon or cuff that inflates within the patient's trachea. The cuffed tracheostomy channels exhaled air between the lungs and the trachea. Once the patient could tolerate the cuffed tracheostomy deflated, a cuffless tracheostomy was used. The cuffless tracheostomy does not have a cuff or balloon around the trachea. Therefore, exhaled air can escape up to the vocal folds and sometimes allow the patient to speak. This patient was able to vocalize with the cuffless tracheostomy. The cuffless tracheostomy is necessary for safe use of the Passy-Muir valve.[26]

† Passy-Muir Inc, 4521 Campus Dr, Ste 273, Irvine, CA 92715.

The Passy-Muir valve is a one-way valve that is placed between the Bodai tracheostomy adapter‡ and mechanical flex-tubing (Flex tube§) when used in conjunction with the ventilator. The Bodai tracheostomy adapter is used because it provides easy access for suctioning and is comfortable for the patient. When the ventilator tubing is moved there is less pressure on the stoma because the Bodai tracheostomy adapter rotates on the tracheostomy (Fig. 4).

Several days after the patient was given the cuffless tracheostomy, the goal was to have him wear the Passy-Muir valve until he felt comfortable for most of the day. Passy-Muir valve tolerance was achieved with the assistance of the patient's speech pathologist and was accomplished in 2 days. When the Passy-Muir valve is used, air is directed out of the patient's mouth during exhalation. The speech pathologist initially monitored the patient using a pulse oximeter to ensure that his oxygen saturation level did not drop below 90% of normal and that he was comfortable while using the Passy-Muir valve. The speech pathologist assisted the patient in coordinating his breathing while using the Passy-Muir valve. Prior to use of the Passy-Muir valve, the patient would speak upon inhalation. With the use of the Passy-Muir valve, the patient used exhalation to speak. The ventilator settings did not change with the use of the Passy-Muir valve.

The Passy-Muir valve allows the inhaled air from the ventilator to fill the patient's lungs, but does not allow the exhaled air to flow out through the tubing for expiration. Instead, the expired air is directed out through the nose and mouth. During inhalation, the Passy-Muir valve prevents air from escaping out through the tracheostomy tubing and directs it into the lungs. The Passy-Muir valve also directs air past the vocal cords for speaking during exhalation. The manufacturer states that inflation of the patient's cuffed tracheostomy when the Passy-Muir valve is in place would cause suffocation because the air the patient receives from the ventilator would be trapped between the lungs and the Passy-Muir valve,[26] which is why a cuffless tracheostomy is used with the Passy-Muir valve.

Glossopharyngeal Breathing

Prior to starting the GPB training sessions, the patient was shown a videotape of a therapist explaining GPB and a person who was dependent on a ventilator performing GPB. The patient began the first week of the 5-week program learning how to breathe with the ventilator air in his mouth instead of his tracheostomy (Figs. 4 and 5).

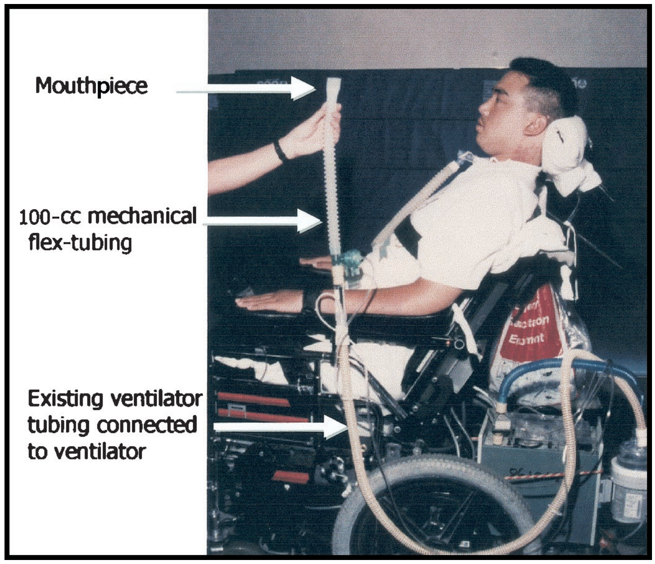

Figure 5.
An additional 100-cc flex-tubing is attached to mouthpiece to allow for quick reconnection.

This was accomplished by attaching a mouthpiece (Calox§) to the ventilator tubing at the level where the tubing attaches to the trachea adapter. The patient would then accept air from the ventilator into his mouth instead of into his trachea. The ventilator settings were not changed from those set when the air entered through his tracheostomy. This manner of breathing with the ventilator mouthpiece will be referred to as *mouth positive air*.

To prevent the air coming into his mouth from escaping through the trachea where it attaches to the flex-tubing, a Passy-Muir valve was put in place between the Bodai tracheostomy adapter and the mechanical flex-tubing. The patient wore the Passy-Muir valve whenever GPB training occurred. While the patient used the air to breathe from his ventilator into his mouth, he learned 2 primary skills necessary for learning GPB. First, he learned how to close off his nasopharynx as he inhaled the air coming into his mouth from the ventilator. I placed a mirror under the patient's nose. If the mirror did not fog during inhalation, then the patient was achieving adequate closure of his nasopharynx. The second skill was to ensure that the patient's chest was rising during inhalation while he received air into his mouth from the ventilator. The patient's chest rising during inhalation indicated that the air was going into his lungs. By the end of the first week, the patient was able to breathe comfortably for 5 minutes with the ventilator delivering air into his mouth.

The second week involved teaching the patient 3 additional exercises that are similar to performing GPB. These exercises were taught while the patient used mouth positive air.

‡ Sontek Medical Inc, 20 Pond Park Rd, Hingham, MA 02043.
§ Puritan Bennett Corp, 2200 Fairaday, Carlsbad, CA 92008.

Table 2.
Steps 1 Through 4 for Physiology of One Glossopharyngeal Breathing (GPB) Stroke

Step 1:	Air enters oral pharynx (concurrent events)
	Mouth opens; air enters as patient reaches out with lips rounded
	Pharynx is widened to allow more room for air to enter
	Floor of mouth, larynx, and tongue depress
	Tongue flattens and the tip touches posterior mandibular dentition
	Glottis is closed
Step 2:	Air is trapped in oral pharynx
	Patient shapes lips as if to say "oop" but instead makes an "up" sound just before lips close
	Lips close and trap air in the pharynx while the glottis remains closed
	Cheeks compress
Step 3:	Air enters lungs
	Lips remain closed
	Soft palate, floor of mouth, larynx, and dorsum of tongue elevate as the tongue sequentially rolls to propel air into the pharynx
	Pharynx constricts, glottis opens, and air passes into the larynx
Step 4:	Air is trapped in the lungs
	Glottis immediately closes, trapping the air in the trachea and lungs as a result of prior steps
	Procedure is repeated 8–12 times
	Accumulated air is exhaled by immediate opening of the glottis

The first exercise involved having the patient take a breath of mouth positive air, close his glottis to keep the air in his lungs, open his mouth, pause, then exhale the air by making an "ahhhhhh" sound. This exercise was intended to help the patient to learn how to open and close his glottis.

The second exercise taught him how to open and close his vocal cords quickly to close his glottis for alveolar gas exchange. When a gulp of air is taken into the pharynx during GPB, the vocal cords need to be opened and closed quickly to trap air below the glottis and the lungs. He performed this second exercise by taking a breath of mouth positive air, closing his glottis to keep the air in his lungs, opening his mouth, pausing, then exhaling by quickly starting and stopping the flow of air while making a sharp "ah, ah, ah" sound until all of the breath of air was exhaled. He was instructed to make this sound quickly and staccato-like.

The third exercise was intended to help the patient to learn to depress and elevate his larynx while holding air in his closed glottis. This involved taking a breath of mouth positive air, closing the glottis, opening his mouth, and then depressing and elevating the posterior portion of his tongue several times while the tip of the tongue maintained contact behind the posterior lower dentition. Then he exhaled the air held below his glottis.

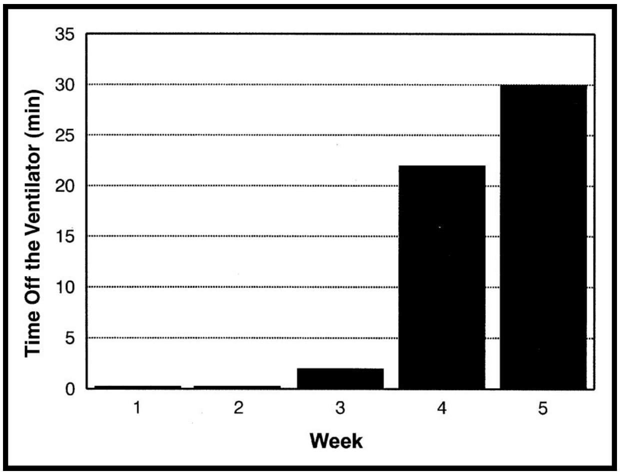

Figure 6.
Time off ventilator while learning glossopharyngeal breathing improved from 0 minutes at week 1 to 30 minutes at week 5.

By mimicking the physical therapist and occasionally watching himself in the mirror, the patient was able to perform a GPB stroke (steps 1–4 in Tab. 2). He was instructed to make an "up" sound with each gulp of air (GPB stroke) while his lips moved in the shape of "oop." Oxygen saturation was monitored during these exercises and never dropped below 97% of normal.

During the third week of GBP training, the patient continued to practice and became more efficient using GPB. He discovered one night while using GPB as his nurses transferred him to his bed that he no longer needed to make an "up" sound or exaggerate with his lips, to perform GPB. He reported feeling less fatigue in his jaw and therefore an ability to perform GPB longer. Using GPB in this way, he was able to breathe off the ventilator for 2 minutes with a vital capacity of 1,600 cc and oxygen saturation level at 98% and above. The patient's oxygen saturation level was monitored by an Ohmeda Biox 3700 pulse oximeter[‖,27] whenever he was disconnected from the ventilator, and vital capacity was measured with a Wright respirometer.

The patient had mastered the GPB stroke by the fourth week. He had a vital capacity of 2,000 cc after 22 minutes off the ventilator with oxygen saturation at 96% and above. At this point, I compared the patient's chest expansion with the ventilator with expansion while using GPB off the ventilator. He was able to expand his chest, measured at the xiphoid process, 9 mm with GPB off the ventilator compared with 3 mm with the ventilator alone. In addition, he was able to perform a weak functional cough both on and off the ventilator using GPB. A weak functional cough would allow him to clear some tracheal secretions independently.[19] He accom-

‖ Datex-Ohmeda Inc, 1315 Century Dr, Louisville, CO 80027.

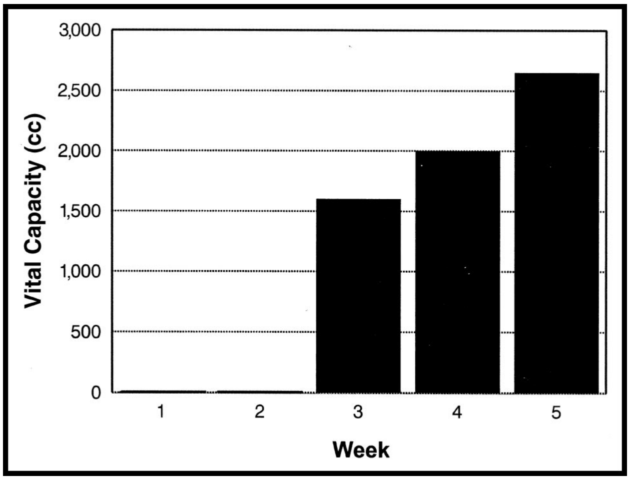

Figure 7.
Vital capacity using glossopharyngeal breathing measured over 5-week period increased from 0 cc at week 1 to 2,650 cc at week 5.

Table 3.
Blood Gas Values While Breathing Off the Ventilator for 30 Minutes Using Glossopharyngeal Breathing[a]

	Patient's Values	Normal Ranges
pH	7.37	7.35–7.45
P_{CO_2}	44 mm Hg	38–50 mm Hg
Pa_{O_2}	91 mm Hg	83–108 mm Hg
HCO_3	25 mmol/L	22–29 mmol/L
Standard base excess	0 mmol/L	
Oxygen saturation	97%	95%–99%

[a] P_{CO_2}=partial pressure of carbon dioxide, Pa_{O_2}=arterial partial pressure of oxygen, HCO_3 = bicarbonate.

plished this cough by first holding a breath from the ventilator in his lungs, then performing GPB, and coughing just prior to the next ventilator breath. His vital capacity with coughing was 3,000 cc.

After 5 weeks of GPB training 3 to 4 times per week for 20- to 30-minute sessions with the physical therapist or physical therapist assistant, the patient was able to use GPB to breathe off the ventilator for 30 minutes (Fig. 6).

The patient may have been able to breathe longer off the ventilator, but 30 minutes was deemed adequate by the patient and the physical therapist as this would allow adequate time for assistance in the event he was accidentally disconnected from the ventilator. His vital capacity was 2,650 cc (Fig. 7).

He could perform a weak functional cough to clear tracheal secretions, and his chest expanded 9 mm at the xiphoid process. A respiratory therapist did a blood gas analysis as the patient performed GPB off the ventilator for just over 30 minutes. His blood gases were normal (Tab. 3).

After the patient mastered GPB, I instructed him in NAMB. The primary neck accessory muscles that he could use were the sternocleidomastoid and scalenus. Strengthening exercises for the neck accessory muscles included manual resistance from the therapist and use of mouth sticks, and operating a chin-controlled power wheelchair. Neck strengthening exercises were performed with the patient by the physical therapist assistant 3 to 5 times per week during the entire inpatient program. The exercises were resistive throughout range of motion and isometric with 5-second hold resistance provided to the patient's head by the physical therapist assistant's hand to strengthen the neck flexors, neck lateral flexors, and neck extensors and with neck flexion with rotation to isolate the sternocleidomastoid muscles. Immediately after the patient successfully completed the GPB training program, he began NAMB off the ventilator with the use of biofeedback. The Verimed Myoexerciser biofeedback machine[#] was used with 2 electrodes attached to each sternocleidomastoid muscle to visually show the patient how to use these muscles for respiration. The first day, he remained on the ventilator for a few minutes while using the biofeedback to practice before being disconnected from the ventilator. Next, while using the biofeedback, he was taken off the ventilator and he performed NAMB until his oxygen saturation level dropped below 90% of normal. This was repeated several times during each training session. Biofeedback sessions were held 4 or 5 times per week for 20 to 30 minutes per session.

After 4 weeks of training, the patient was able to use his neck accessory muscles to breathe off the ventilator for 2 minutes before his oxygen saturation level dropped below 90% of normal. Further training was discontinued because the patient was frustrated with his lack of progress.

Outcomes

After 5 weeks of GPB training 3 to 4 times per week, the patient was able to perform GPB off the ventilator for 30 minutes (Fig. 6) with a vital capacity of 2,650 cc (Fig. 7). His cough improved from nonfunctional to weak functional, which allowed him to clear tracheal secretions. He could take a deep breath and expand his chest from 3 mm with the ventilator alone to 9 mm using GPB.

The patient was only able to use NAMB for 2 minutes before his oxygen saturation level dropped below 90% of normal. After 4 weeks, training to breathe with neck

[#] Verimed, 101 NW 62nd St, Ste 212, Ft Lauderdale, FL 33309.

accessory muscles was discontinued because the patient became frustrated with his lack of progress.

The patient was discharged from the rehabilitation center to a residential home that provided 24-hour nursing care. While at this home, he was encouraged by the nursing staff to continue to practice NAMB off the ventilator. The patient stated that he was able to breathe off the ventilator with his neck accessory muscles for 4 minutes at a time after living at the residential home for 2 years. He rated difficulty in learning to use his neck accessory muscles to breathe off the ventilator as 9 out of 10, where 10 is "very difficult."

I interviewed the patient by telephone 4 years after his inpatient rehabilitation program. He was living in his own home with 24-hour nursing care while attending college to obtain a degree in computer science. When asked to recall his experience learning GPB, he commented that he knew he was getting air into his lungs with GPB because he could see his chest rising and his ribs expand. He explain that he used counting as a method to pace himself to ensure he would not breathe too rapidly, become anxious, and then become tired when using GPB to breathe off the ventilator. He would exhale once he had a feeling he could not accommodate further breaths. He reported that the easiest portion of performing GPB is pushing the air into the lungs. The most helpful information he received while learning GPB was to use his tongue in order to "squash" air into his lungs. He related GPB to making himself "burp," but instead of exhaling his "burp," he would force the air into his lungs. He rated the difficulty of learning GPB as 5 out of 10, where 10 is "very difficult." At the time of this writing, he was using GPB for 1 hour per day for transfers and dressing and sometimes for bathing.

He described using GPB to cough while he was on the ventilator by first using a ventilator breath, then a "sip of air" [GPB] followed by a cough before the next ventilator breath. After the patient had learned GPB, he was asked how GPB has helped him. He stated, "It has given me peace of mind when I'm off the ventilator. I feel safe, confident. Before, whenever I was off the ventilator, I was pretty scared. Now, I know I will be okay. I won't panic. I can keep a cool head."

Discussion

Respiratory complications and the potential for accidental disconnection from the ventilator are life threatening to individuals with high tetraplegia who are dependent on ventilators to breathe. In addition to reducing fear and anxiety, emergency breathing techniques provide a potentially life-saving alternative breathing method in the event of ventilator disconnection and may reduce the risk of respiratory complications by allowing a more functional cough.

Several factors need to be considered when instructing patients to use GPB. Glossopharyngeal breathing is contraindicated for people who do not have normal vasomotor reflexes, because inspiration is prolonged and results in a high bronchial pressure, which decreases venous return to the heart and, in turn, causes low blood pressure.[6,16,17] If low blood pressure occurs, the patient may complain of fullness in the head or feeling faint.[17] To prevent this low blood pressure effect, the tidal volume should be maintained at 1,000 cc. In addition, if the time for taking the breath is not prolonged, then minimal blood pressure changes will occur. It is safe to take an occasional deep breath using GPB for coughing or chest stretching.[6,16] If the patient has laryngeal irritation, learning GPB will be more difficult and may result in poor coordination and laryngeal spasm. Glossopharyngeal breathing is a voluntary activity and requires the individual to be awake.[17] If patients have weakness of the anatomical structures used for swallowing, then they will have difficulty learning GPB because the same anatomical structures are used for both swallowing and GPB.

Glossopharyngeal breathing was a more effective breathing technique for this patient than NAMB. In my experience, several differences between GPB and NAMB explain why this patient and others may have more success learning one breathing technique over the other. First, NAMB is typically easier to learn because people are familiar with the use of these muscles for activities requiring strenuous breathing, such as running. Glossopharyngeal breathing may be more difficult to learn because it is not a natural method to breathe. Second, people with smaller body sizes will be more successful using NAMB than heavier people, who often have difficulty because the neck accessory muscles are not designed to support the body weight for respiration. The size of a person's body does not affect the ability to learn GPB. This may explain why children in some studies were able to learn NAMB.[7,9] The patient in this case report weighed 86.2 kg, which may help to explain why he was more successful with GPB and learned it more easily than NAMB. Third, it does not matter where the ventilator is disconnected in order to use NAMB; however, a Passy-Muir valve or plugged tracheostomy is required for GPB to be effective. This is one reason why I believe therapists should consider offering training for both techniques to patients whenever possible.

All research to date involving people who are dependent on a ventilator and learn GPB has been done with individuals who have poliomyelitis and Duchenne muscular dystrophy. No published accounts of the use of GPB were found with people who are dependent on a ventilator because of tetraplegia secondary to a spinal cord injury. Because of the development of the Salk vaccine, fewer individuals have poliomyelitis today. As a result, fewer clinicians and patients know about GPB or how to learn and perform it. Glossopharyngeal breathing may have important application to patients today, and this technique should continue to be taught and used. Neck accessory muscle breathing is a common alternative breathing technique that also needs to continue to be used, but it does not allow the functional cough or chest expansion that GPB provides. Alternative breathing techniques may also benefit other patients with respiratory muscle paralysis, such as muscular dystrophy and Guillain-Barré syndrome.

Glossopharyngeal breathing was learned easily by people who had poliomyelitis by mere suggestion or demonstration and has been successfully taught to patients for the past 50 years at Rancho Los Amigos National Rehabilitation Center.[5,6,11,13,17] It is possible that more people with respiratory muscle paralysis could learn GPB if they were made aware of it. People with poliomyelitis are living today who are able to perform GPB and from whom clinicians can learn.

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