ORIGINAL ARTICLE

Comparison of speech parameters and olfaction using different tracheotomy speaking valves

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Background: The objective of this work was to obtain a controlled subjective and objective in vivo clinical comparison of the Passy-Muir, Shiley, and Ball speaking valves.

Methods: Ten patients free of laryngeal pathology but dependent on tracheotomy for respiration were tested with each of the speaking valves. Olfaction was assessed for each patient using the University of Pennsylvania Smell Identification Test (UPSIT). Acoustic and perceptual analyses included subjective assessments, noninstrumental objective assessments (including maximum phonation time, and S:Z ratio), and instrumental objective assessments (including fundamental frequency:maximum phonation range, vocal intensity, perturbation, naturalness, and turbulence). Oxygen saturation was assessed by pulse oximetry.

Results: There was a highly significant statistical difference in olfaction and speech naturalness, in favor of the Ball valve. The Ball valve's speech parameters were generally better than with the Passy-Muir and Shiley valves, including maximum phonation, S:Z ratio, jitter, noise, and turbulence, although the differences were not statistically significant. There were no differences among the valves in oxygen saturation levels.

Conclusion: This study illustrates that olfaction and certain speech parameters, most noticeably speech naturalness, are significantly improved with the Ball valve as compared to the Passy-Muir and Shiley valves.

Key Words:
olfaction; speech naturalness; tracheotomy speaking valve; Passy-Muir valve; Shiley valve; Ball valve

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Tracheotomy affects the patient at a very basic level: the ability to communicate. With the presence of a tracheotomy tube, air flow is diverted away from the vocal folds, often making the patient aphonic. One-way speaking valves are designed to direct exhaled air over the vocal folds in order to restore speech. These valves generally attach to the hub of the tracheotomy tube and allow air to be inspired through the valve and into the tracheotomy tube. On expiration, the valve closes so that air can not exit via the tracheotomy tube; rather, the exhaled air is forced to exit via the upper airway. The use of a tracheotomy-speaking valve enables the patient to speak without having to occlude the tracheotomy tube via the finger, which has several limitations. First, placing a finger over the lumen requires manual dexterity that many patients lack. Second, it requires coordination of phonation with breathing. Finally, finger occlusion is unsanitary.

A variety of 1-way speaking valves have been described in the literature and are on the market. These include the Passy-Muir^{TM} valve (Passy-Muir, Inc.), the Shiley Phonate^{TM} valve (Mallinckrodt Medical), the Kistner^{TM} valve (Pilling Weck^{TM}), the Olympic Trach-Talk^{TM} (Olympic Medical), and the Montgomery^{TM} speaking valve (Boston Medical Products).[1–4] The Shiley, Montgomery, and Kistner valves operate via flap; the Olympic Trach-Talk operates spring-loaded but is at present rarely used. The Passy-Muir valve, which is currently the flapper valve most commonly used by clinicians, is the only valve that has "positive closure," meaning that the valve stays closed except when the patient inhales (this feature is also Q1

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called "biased-closed"). In theory, this is beneficial because it allows the valve to be used with ventilator-dependent patients when the tracheotomy tube cuff is deflated; however it presents a disadvantage as well because it requires an inspiratory effort to open the valve, which with extended usage may cause young children and/or adults with limited pulmonary function and/or neurologic diagnoses to fatigue prematurely.[5]

A newer type of unidirectional speaking valve, the Ball speaking valve, is based on a moving ball inside a chamber.[6] With the patient sitting in the resting state, the ball naturally lies close to the posterior opening of the chamber, because the valve angle is 20 degrees from the horizontal axis of the cannula (this corresponds to a "biased-open" position). Upon inspiration, the ball moves further back toward the trachea but is stopped by a piece of wire that runs across the diameter of the valve body, and air enters the cannula as with normal breathing. On exhalation, the ball is flipped forward and comes to rest in the valve opening, blocking air flow through the cannula and forcing the air to flow through the larynx, as with normal expiration, hence allowing speech.

One advantage of the Ball valve over the Passy-Muir or Shiley flapper speaking valves is that it offers substantially lower in vitro airflow resistance.[6–8] Fornataro-Clerici and Zajac[8] investigated the resistance of 4 different valves (Kitsner, Montgomery, Olympic, and Passy-Muir). They found that the Kistner valve had significantly higher resistance to airflow than the other 3 valves. Moreover, significantly higher pressures were required to open the Passy-Muir valve in comparison to the Olympic and Montgomery valves.

Voice quality also differs among valves. During investigation of listeners' preferences, the Montgomery and Passy-Muir valves were judged to have superior intelligibility when compared with the Kistner and Olympic valves.[89] The within-subject design identified no difference in patient comfort among the 4 valves, however. Listeners also identified clinical problems (eg, clicking and hissing) associated with the different speaking valves, which may have been influenced by the closure of the valve on expiration.[8,9] An air leak on expiration was identified in both the Montgomery and Olympic valves, while the Passy-Muir valve demonstrated no leak on expiration. The authors hypothesized that the Passy-Muir valve had no leak secondary to its "bias-closed" design. All other valves in the study were "bias-open."

Whether the mechanical functioning of the valves translates into a better clinical outcome is not clear, because studies in this area have been generally anecdotal, poorly controlled, and highly subjective. Other questions awaiting objective analysis include the claims that speaking valves result in increased oxygenation and improved olfaction.[10,11] Hyposmia is a well-recognized phenomenon in patients who have had their nasal airflow diverted through a tracheotomy or a laryngectomy.[2,12–17] It was suggested that this results in elevated olfactory detection thresholds. Speaking valves have been reported to result in smell improvement,[2,10] possibly by redirecting airflow to the nasal cavity; however, objective olfactory studies are lacking.

The purpose of this investigation is to perform an objective comparison between the Ball valve, the Passy-Muir valve, and the Shiley valve with regard to olfaction, acoustic performance, and oxygenation. This prospective study was approved by our Institutional Review Board.

Patients and methods

Subjects

Ten patients free of laryngeal pathology but dependent on tracheotomy for respiration were identified. Reason for tracheotomy dependency included obstructive sleep apnea, tracheomalacia, chronic pulmonary disease, need for respiratory support, and frequent aspiration. These subjects met the following inclusion criteria: (1) able to tolerate a cuffless tracheotomy tube for approximately 4 hours; for the sake of standardization, the tracheotomy tubes were changed at the initiation of the study and all patients were tested wearing a Shiley 6 tracheotomy tube; (2) no known laryngeal pathology or vocal fold paralysis; (3) no overt speech deficits; (4) able to consistently follow 1-step commands; and (5) able to provide informed consent. Participation in this study was purely on a volunteer basis. The details of this study were presented to the patients and a signed consent was obtained. The subjects were randomly assigned to all of the 3 valves and evaluated for the parameters described below.

Oxygen saturation

Each patient had his/her oxygen saturation and heart rate monitored for the duration of his/her test period, covering olfaction and acoustic/perceptual analysis (approximately 1 hour for each valve). These rates were made using a calibrated (Criticare Systems, Inc., 502) pulse oximeter. Measurements were recorded (1) prior to the placement of any speaking valve and (2) at the completion of 1 hour of continuous valve use (for each valve). All measurements were recorded in log fashion including: time of measurement and saturation level for each activity and valve worn. The evaluating investigators were blinded and patients were identified by initials and date of birth (DOB) only.

Olfaction

Olfaction was assessed using the University of Pennsylvania Smell Identification Test (UPSIT), a standardized, commercially available 40-stimulus microencapsulated "scratch-and-sniff" odor identification test.[18] The patients repeated this test for each of the 3 valves and the speaking valves were changed to conform to a predetermined randomized order of valve use. Olfaction assessment was completed in a "round-robin" fashion (ie, patients completed all measurements wearing 1 valve, and then repeated the series of measurements wearing a different valve). A 15-minute rest/adjustment period was provided between each valve change to take into account that there can be a fatiguing effect with olfactory stimuli and that there may be a test-retest phenomenon if the same test is administered multiple times to the same subject. The evaluating investigators were blinded to the type of valve worn.

Acoustic/perceptual evaluation

The patient's speaking valves were changed to conform to a predetermined randomized order of valve use. All acoustic and perceptual assessments were completed in a "round-robin" fashion (ie, patients completed all measurements wearing 1 valve, and then repeated the series of measurements wearing a different valve). A 5-minute rest/adjustment period was provided between each valve change. The evaluating investigators were blinded to the type of valve worn.

Subjective

Assessment included the subject's reading of a copy of the "Grandfather" passage aloud.[19] Each subject read the stimulus 3 times (ie, once with each speaking valve), into a unidirectional microphone (Sony ECM-170) connected to a reel-to-reel tape recorder (ReVox B77) with a noise reduction circuit (Dolby B). This reading was recorded on a high-bias tape (AMPEX 407). A mouth-to-microphone distance of 10 cm was maintained. Five adults with varying backgrounds (ie, 2 speech-language pathologists, 1 secretary, 1 physician, and 1 social worker) listened to the audiotapes. The 3 readings, corresponding to the 3 different valves, were rank-ordered on a 4-point scale (4 = best, to 1 = worst) for speech quality and naturalness (ie, a combination of production and intelligibility), within each subject. In addition, subjective listener comments (eg, voice quality or extraneous valve noises) were noted for each reading. The stimulus was presented to each listener 3 times in order to complete all judgments. The evaluating investigators were blinded to the type of valve worn.

Noninstrumental objective

The speech-language pathologist (SLP) obtained the measurements for each subject during each speaking valve condition. Each sample was audio recorded to allow for independent confirmation from a blinded SLP.

Maximum phonation time

The ability to sustain phonation of a vowel. The patients were instructed to "take a deep breath" and sustain the vowel /ah/ for as long as possible. A stopwatch was used to measure the duration of this vowel. Three trials were performed for each valve, with the greatest duration being adopted as the maximum phonation time.

S:Z ratio

This is a technique used to determine the presence of absence of vocal nodules of other true vocal fold pathology. Theoretically, if the respiratory system is compromised and the laryngeal system is intact, there should be an equal reduction in expiratory flow for the "voiceless" sound /s/ and the "voiced" sound /z/. The patients were instructed to take a deep breath and then sustain a /s/ for as long as possible. The examiner demonstrated the task. Each subject repeated the procedure 3 times, with the longest duration (determined by stopwatch) taken as the score. The same procedure was taken for the /z/ sample. The ratio was obtained by dividing the maximal /s/ value by the maximal /z/ value. A ratio of 1.4 or above may indicate a degree of vocal fold dysfunction.

Instrumental objective

These measurements were obtained by the speech-language pathologist using the Kay Elemetrics Computerized Speech Lab (CSL 4300B 5.X). Subjects spoke into a head-mounted microphone (Akgacoustics c420) with a windscreen tip. Input levels to the CSL were kept constant across subjects and were noted at the time of the study. Each measurement was recorded on a hard disk. Data were analyzed via 2 built-in programs in real-time-Pitch and Multidimensional Voice. The evaluating investigators were blinded to the type of valve worn.

Maximum phonation range

The subject was asked to say /ah/ at a comfortable pitch. S(he) was then instructed to lower the pitch gradually until s(he) had reached the lowest pitch possible. The subject then returned to the comfortable pitch, and was instructed to gradually raise the pitch until s(he) had reached the highest possible pitch. A practice task was used to ensure subject understood.

Vocal intensity

The subject produced the softest /ah/possible, and then the loudest /ah/ possible at a comfortable pitch for the subject. The average intensity was calculated during a reading of the first sentence of the Grandfather passage).

Perturbation

Small, rapid, cycle-to-cycle changes of period and amplitude that occur during phonation. The subject was asked

TABLE 1. Analysis of differences in olfaction and speech perception parameters between the Ball valve, Shiley valve, and Passy-Muir valve

	Shiley valve (mean ± SEM)	PMSV (mean ± SEM)	Ball valve (mean ± SEM)	p
Olfaction	28.30 ± 2.05[a]	28.70 ± 1.90[a]	33.40 ± 1.38[b]	<0.001
Naturalness	2.30 ± 0.15[a]	2.20 ± 0.20[a]	2.80 ± 0.13[b]	0.001
Maximum phonation	14.01 ± 1.86	14.12 ± 1.85	17.59 ± 2.82	0.07
S:Z	0.16 ± 0.02	0.15 ± 0.02	0.19 ± 0.03	0.06
Jitter	3.02 ± 0.73	3.49 ± 0.79	2.71 ± 0.61	0.08
Noise	0.35 ± 0.07	0.42 ± 0.08	0.29 ± 0.06	0.11
Turbulence	0.30 ± 0.14	0.40 ± 0.15	0.22 ± 0.09	0.39
Intensity	63.80 ± 3.69	64.30 ± 3.89	63.00 ± 3.48	0.18

Values of p determined by analysis of variance with device treated as a repeated measure. Values with unique lowercase superscripts are different from each other as determined by Tukey's post hoc analysis.

PMSV = Passy-Muir Speaking valve; SEM = standard error of the mean.

TABLE 2. Analysis of differences in oxygen saturation between the Ball valve, Shiley valve, and Passy-Muir valve*

	Shiley valve (mean ± SEM)	PMSV (mean ± SEM)	Ball valve (mean ± SEM)
O_2 saturation			
Baseline	97.30 ± 0.93	97.30 ± 0.93	97.30 ± 0.93
15 minutes	96.80 ± 0.78	96.40 ± 0.86	97.00 ± 0.80
30 minutes	96.10 ± 0.91	96.00 ± 1.05	97.30 ± 0.88

*Calculations by 2-factor analysis of variance. Main effects: speaking valve, $p = 0.85$; time = 0.09.

PMSV = Passy-Muir Speaking Valve; SEM = standard error of the mean.

to sustain /ah/ at a "comfortable pitch" for 5 seconds. The amounts of shimmer (amplitude variation) and jitter (frequency perturbation) were calculated.

Naturalness

The speech naturalness scale is a measure of how fluent and natural the speech sounds. This was a visual analog scale or rating from 1 to 9, where, for example 1 is extremely natural sounding speech and 9 is extremely unnatural. This is most frequently used in stuttering. It was used to reflect abnormal phrasing and to see if clicking was a problem.

Turbulence

The Voice Turbulence Index (VTI) is an average ratio of the spectral inharmonic high-frequency energy. It correlates primarily with the turbulence caused by incomplete or loose adduction of the vocal folds.

Statistical analysis

Data was analyzed by analysis of variance (ANOVA) with the device treated as a repeated measure because each device was tested in each individual patient. If significance was found ($p < 0.05$), a post hoc test (Tukey's) was used to determine which devices were different from each other. For oxygen saturation a 2-way ANOVA was used to test for both device and time effects.

Results

The Ball device was significantly superior to the other 2 devices for olfaction ($p < 0.001$) (Table 1 and Fig. 1). For the various voice or pitch tests, the Ball device was superior to the 2 other devices ($p = 0.001$) for naturalness (Table 1 and Fig. 2). The Ball valve showed better speech parameters than the Passy-Muir and Shiley valves in maximum phonation, S:Z ratio, jitter, noise, and turbulence, although the difference not statistically significant. There was no difference in oxygen saturation among the 3 valves ($p = 0.85$) or for the times ($p = 0.09$) when saturation was measured (Table 2).

When asked to give a subjective evaluation of the 3 valves (they were asked "which one do you prefer"), 8 of the 10 subjects preferred the Ball valve and 2 preferred the Passy-Muir valve. Six subjects found the low profile to be the most important characteristic of a speaking valve (hiding the appearance of the neck device was an important characteristic for the tracheotomy patients) and 4 found ease of breathing to be the most important characteristic.

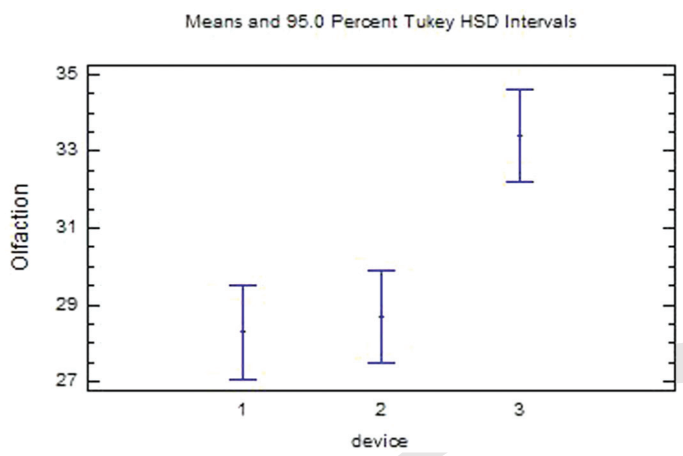

FIGURE 1. Olfaction scores with the various speaking valve devices: device 1 is the Shiley valve, device 2 is the Passy-Muir valve, and device 3 is the Ball valve.

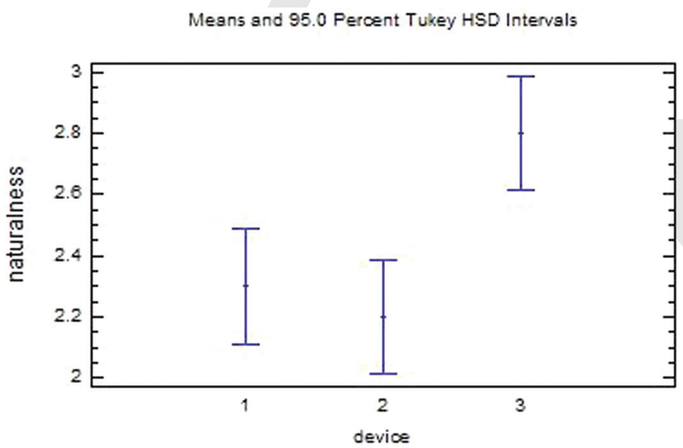

FIGURE 2. Naturalness scores with the various speaking valve devices: device 1 is the Shiley valve, device 2 is the Passy-Muir valve, and device 3 is the Ball valve.

Discussion

This work provides a clinical comparison of the Passy-Muir, Shiley, and Ball speaking valves. Five blinded adults with varying backgrounds independent of the author (2 speech-language pathologists, 1 secretary, 1 physician, and 1 social worker) were chosen to listen to the audiotapes. The study found that the Ball valve was significantly superior to the other 2 valves for olfaction and speech naturalness. Speech quality was generally better with the Ball valve, as compared to both the Passy-Muir and Shiley valves, in 5 of the speech parameters measured (maximum phonation, S:Z ratio, jitter, noise, turbulence), but these differences were not statistically significant. We did not note any significant difference in oxygen saturation levels after 15 minutes or 30 minutes of use in either valve. This was not surprising in view of the fact that none of the subjects had any difficult breathing while wearing the speaking valves. It is also consistent with prior findings that mechanical resistance caused by speaking valves in the healthy adult tracheotomy population, is not significant enough to affect oxygenation.[8,9] Whether this may prove to be different in young children or in patients with neurologic and/or pulmonary deficits needs further evaluation.

This study confirms the well-known fact that redirection of airflow away from the nasal cavity by a tracheotomy, causes decreased and/or delayed olfactory sensitivity as evidenced by reduced olfactory identification scores,[2,9,13–16] and also confirms the fact that wearing a speaking valve improves olfaction. This was assessed using UPSIT, an olfactory identification test that correlates better with the odor identification than olfactory threshold testing, but that nevertheless is not a perfect olfactory test. UPSIT is predicated upon microencapsulated odors. The scoring of these tests typically follows a classical test theory approach, which assumes that the number of correctly identified stimuli, ie, the "raw score," can be used as a measure of a person's olfactory identification ability. Limitations of UPSIT are that raw scores provide only ordinal indices of olfactory identification ability, and such scores are inherently specific to the particular set of olfactory stimuli that were included in the test. UPSIT testing showed that the Ball valve was superior to the Passy-Muir and the Shiley valves. The precise reason for the superior olfaction with the Ball valve over the Passy-Muir and the Shiley valves is not quite clear; however, we venture that the well-documented lower in vitro airflow resistance associated with the Ball valve,[6] results in improved breathing and a more effective and sustained redirection of airflow toward the nasal cavity. The physiology literature confirms that higher and longer nasal airflow are associated with elevated olfactory detection thresholds and improvement in odorant detection.[20,21] The ability to improve smell is a significant advantage for tracheotomy patients, as olfactory impairment negatively impacts quality of life and worsens disability.[22]

When the subjects were asked about their subjective personal preference, 8 chose the Ball valve, and 2 chose the Passy-Muir valve. The reasons quoted were as follows: (1) the low profile of the valve, by 6 subjects; and (2) the ease of breathing, by 4 subjects. All valves were found to exhibit a soft click/hiss with speech production; however, the subjects did not describe it as being significantly different among the 3 valves.

Conclusion

Our study confirmed the well-documented fact that olfaction is decreased in tracheotomy patients and shows that the Ball valve significantly improves the loss of smell, as compared to the Shiley or the Passy-Muir valves. Acoustic and perceptual evaluation was generally more favorable with the Ball valve, most significantly with regard to speech naturalness. We did not note any significant difference in oxygen saturation levels. Eight out of 10 subjects subjectively preferred the Ball valve, and 2 preferred the Passy-Muir valve.

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Queries

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