Effects Of Cuff Deflation And One-Way Tracheostomy Speaking Valve Placement On Swallow Physiology

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Abstract

This study examined the effects of trache- ostomy cuff deflation and one-way speaking valve placement on swallow physiology. Fourteen non- ventilator-dependent patients completed videofluoroscopic swallow studies (VFSS) under three conditions: (1) cuff inflated, (2) cuff deflated, and (3) one-way valve in place. Four additional patients with cuffless tracheostomy tubes completed VFSS with and without the one-way valve in place. All swallows were analyzed for the severity of penetration/aspiration using an 8-point penetration–aspiration scale. Seven preselected swallow duration measures, extent of hyolaryngeal elevation and anterior excursion, and oropharyngeal residue were also determined. Scores on the penetration–aspiration scale were not significantly affected by cuff status, i.e., inflation or deflation. However, one-way valve placement significantly reduced scores on the penetration–aspiration scale for the liquid bolus. Patients who are unable to tolerate thin liquids may be able to safely take thin liquids when the valve is in place. However, one-way valve placement may not be beneficial for all patients. Clinicians who complete VFSS with tracheostomized patients should include several bolus presentations with a one-way speaking valve in place before making any decisions regarding the use of the valve as a means to reduce aspiration.

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Introduction

Investigators have suggested an association between the presence of a tracheostomy tube and an increased risk of aspiration [1–4]. There are several possible explanations for why aspiration occurs in these patients, including: (1) decreased elevation and anterior rotation of the larynx due to the anchoring of the trachea to the strap muscles and skin of the neck created by the inflated tracheostomy tube cuff [3,5,6]; (2) esophageal compression created by impingement of the tracheostomy cuff on the esophageal wall [7]; (3) significant attenuation of the adductor vocal fold reflex resulting from a lack of airflow through the upper airway [8]; (4) gradual decrease in abductor vocal fold activity [8]; and/or (5) reduction in subglottal air pressure [9,10].

In an attempt to identify an association between the presence of a tracheostomy tube and an increased risk of aspiration, Leder and Ross [11] examined swallow function in 20 patients pre- and posttracheostomy and found no causal relationship between tracheostomy and aspiration. The authors concluded that patients with tracheostomy tubes often have risk factors other than the presence of a tracheostomy tube that predispose them to aspirate (e.g., chronic obstructive pulmonary disease or head injury).

Many patients aspirate, including a number of patients with tracheostomy tubes. Given the reportedly high incidence (50%–87%) of aspiration in tracheostomized patients [1,2,4,12] and the potential for the development of aspiration pneumonia, it is essential to evaluate and treat these patients when aspiration is observed. Several approaches to eliminating or reducing aspiration in this patient population have been discussed in the literature. Some have reported that deflating the tracheostomy cuff improves swallow function [13]. To date, no

research has examined the effect of cuff deflation on specific aspects of swallowing physiology, such as hyolaryngeal excursion or cricopharyngeal opening.

Other research has suggested that occluding the tracheostomy tube may improve swallowing. The effects of tracheostomy tube occlusion have been studied in tracheostomized patients with head and neck cancer [14–16]. Results have indicated elimination of aspiration in up to 60% of patients and a reduction in the amount of material aspirated in those patients for whom aspiration was not completely eliminated. Leder et al. [17,18] observed less encouraging results. They examined patients with a variety of diagnoses, including acute respiratory distress syndrome (ARDS), chronic obstructive pulmonary disease (COPD), spinal cord injury, and head and neck cancer, and found that tracheostomy tube occlusion status had no effect on the incidence of aspiration.

While tracheostomy tube occlusion has shown positive effects for some patients, many patients with tracheostomy tubes are unable to tolerate complete occlusion of the tracheostomy tube but can tolerate placement of a one-way valve. Several studies have indicated that placement of a one-way speaking valve helps to eliminate or reduce aspiration in tracheostomized patients [19–21]. However, others [22] have found that the one-way valve has no effect on the incidence of aspiration.

Given the paucity of data regarding the effect of cuff deflation on swallowing and the conflicting reports in the literature regarding the effect of one-way valve placement on the prevalence of aspiration, further investigations are warranted. The purpose of this study was to determine the incidence of aspiration in individuals as a function of three conditions: (1) cuff inflated, (2) cuff deflated/cuffless, (3) one-way valve. The second purpose of the study was to determine the physiologic changes in swallowing as a function of the three above-stated conditions.

Methods

Participants

Participants were recruited from the University of Tennessee Medical Center, Knoxville. Twenty-two consecutive individuals with tracheostomy tubes, who were referred by their attending physician for a videofluoroscopic swallowing study (VFSS) due to suspected oropharyngeal dysphagia, completed an initial VFSS. Of the 22 patients, 18 had cuffed tracheostomy tubes and four had cuffless tracheostomy tubes. Selection criteria were (1) nonventilator dependence, (2) ability to tolerate cuff deflation during the VFSS, as determined by a respiratory therapist who monitored oxygen saturation and heart rate throughout the testing session, (3) no surgery to the upper aerodigestive tract except tracheostomy, (4) no history of oropharyngeal cancer or stroke, and (5) at least one aspiration occurrence on thin liquid or puree without the one-way valve in place during the videofluoroscopic swallow study. Individuals with cuffed tracheostomy tubes demonstrated aspiration on at least one consistency with the cuff inflated during the videofluoroscopic swallow study. Of the 22 patients, 18 met the selection criteria and were included in the final data analysis. Participant profiles are found in Table 1. Thirteen males and five females ranging in age from 19 to 80 years participated. Participants presented with a variety of diagnoses including chronic obstructive pulmonary disease (COPD), acute respiratory distress syndrome (ARDS), and closed head injury. At the time of testing, 17 participants had nasogastric feeding tubes, and one had a percutaneous endoscopic gastrostomy (PEG) tube. All participants had Shiley plastic tracheostomy tubes (Mallinckrodt Medical, St. Louis, MO), with sizes from four to eight. Time from tracheostomy to VFSS ranged from five to 29 days. Time off the ventilator prior to the videofluoroscopic swallow evaluation ranged from 2 to 19 days. All participants had worn the one-way valve (Passy–Muir, Inc., Irvine, CA) at least once prior to the VFSS and were able to tolerate placement for at least 15 minutes. A speech–language pathologist and a respiratory therapist monitored oxygen saturation levels and heart rate during each trial period and determined each participant's ability to tolerate valve usage.

Procedures

All participants completed a VFSS positioned upright and viewed in the lateral plane. A U.S. one-cent coin was placed at the angle of the left mandible to serve as a marker for measuring hyolaryngeal movement. The oral cavity, pharynx, upper airway, and cervical esophagus were radiographically visualized during the entire study. Participants completed a total of 12 swallows in three conditions: (1) cuff inflated, (2) cuff deflated, and (3) cuff deflated with the one-way valve in place. Two liquid boluses (E-Z Paque liquid barium, EZEM, Westbury, NY) and two puree boluses (four parts unsweetened applesauce to one part barium powder, E-Z High Density Barium Sulfate, EZEM, Westbury, NY) were presented under each condition. Participants with cuffless tracheostomy tubes completed only eight swallows, as the cuff-inflated condition was removed. To minimize order effects, presentation under the three conditions was randomized. During the cuff-inflated condition, all participants' tracheostomy cuffs were fully inflated (i.e., no leak). This was confirmed by a respiratory therapist using a Posey Cuff-flator (Posey Company, Arcadia, CA). The clinician that completed the VFSS fed each participant. All boluses were presented via plastic spoon.

The fluoroscopic image of the swallow was recorded (General Electric, Model 152000G2, New York, NY) to allow for real-time and slow-motion analyses. A 100-ms video timer (FOR.A Corp, Model VTG-55, San Jose, CA) was used for detailed, frame-by-frame, timed analysis of the measures employed. Images were held for 3 s after the swallow to allow for viewing of any postswallow aspiration.

Measurements

Two speech–language pathologists reviewed all videotapes in real time and in slow motion. Videotapes were analyzed for the pres-

Table 1. Participant profiles

Participant	Diagnosis	Nutrition	Tracheostomy tube size	Days with tracheostomy	Days off ventilator
1	COPD[a]	N-G Tube[b]	6	20	4
2	CHI[c]	N-G Tube	6	9	6
3	COPD	N-G Tube	6	21	8
4	CHI	N-G Tube	8	14	4
5	CHI	N-G Tube	6	15	3
6	CHI	PEG[d] Tube	6	17	5
7	COPD	N-G Tube	6	15	7
8	CHI	N-G Tube	6	5	2
9	s/p CABG[e]	N-G Tube	4	11	9
10	s/p CABG	N-G Tube	6	7	3
11	CHI	N-G Tube	6	13	2
12	CHI	N-G Tube	6	19	4
13	ARDS[f]	N-G Tube	6	25	14
14	ARDS	N-G Tube	6	26	19
15	ARDS	N-G Tube	6	25	14
16	COPD	N-G Tube	4	18	15
17	CHI	N-G Tube	6	14	4
18	s/p AAA repair[g]	N-G Tube	8	29	11

[a]COPD = Chronic Obstructive Pulmonary Disease.
[b]N-G Tube = Nasogastric Tube.
[c]CHI = Closed Head Injury.
[d]PEG = Percutaneous Endoscopic Gastrostomy.
[e]s/p CABG = Status post Coronary Artery Bypass Graft.
[f]ARDS = Acute Respiratory Distress Syndrome.
[g]s/p AAA Repair = Status post Abdominal Aortic Aneurysm Repair.

ence or absence of penetration or aspiration and the timing of aspiration (before, during, or after the pharyngeal swallow). An 8-point penetration–aspiration scale [23] was employed to determine the severity of penetration/aspiration based on the depth the bolus traveled in the airway and the patient's response.

The following times were recorded in accordance with bolus movement through the oropharynx: (1) begin posterior movement of the bolus, (2) first barium into the pharynx, (3) entrance of the tail of the bolus into the pharynx, (4) begin maximum laryngeal elevation (i.e., the moment at which the hyoid began its ascent), (5) first maximum laryngeal elevation (judged as the moment at which the hyoid first reached its maximum point of elevation), (6) last maximum laryngeal elevation (the last moment at which the hyoid was at its maximum point of elevation), (7) first maximum hyoid anterior excursion (the moment at which the hyoid first reached its maximum anterior excursion), (8) last maximum hyoid anterior excursion (the last moment at which the hyoid was at its maximum anterior excursion), (9) hyoid return to rest, (10) cricopharyngeal opening, (11) entrance of the head of the bolus into the cricopharyngeus, (12) entrance of the tail of the bolus into the cricopharyngeus, and (13) cricopharyngeal closure [24]. The time in milliseconds at which each point occurred was recorded and used to calculate the following duration measures: (1) oral transit duration (OTD), (2) stage transition duration (STD), (3) pharyngeal transit duration (PTD), (4) duration of hyoid maximum elevation (DOHME), (5) duration of hyoid maximum anterior excursion (DOHMAE), (6) duration of cricopharyngeal opening (DOCPO), and (7) total swallow duration (TSD) [24].

Three additional measurements were determined. A three-point scale (0 = "no residue," 1 = "coating," 2 = "pooling") was used to assess the amount of residue in the oral cavity, the valleculae, the posterior pharyngeal wall, the pyriform sinuses, and within the cricopharyngeus. Also, maximum extent of laryngeal elevation and hyoid anterior movement (in mm) were determined. Still frames of each participant's hyolaryngeal structures were traced onto overhead transparencies. The distance from resting hyoid position to maximum hyoid elevation and the distance from resting hyoid position to maximum hyoid anterior excursion were measured in millimeters. In order to adjust for the magnification effect of the videofluoroscopy, the video image of the one-cent coin placed on each participant's left mandible was traced and the diameter was measured. Distance measurements were then multiplied by the magnification correction factor. For example, if the cent was 1 in. wide but appeared to be 2 in. wide on the video image, the distance that the hyoid bone appeared to move was divided by two to correct for the magnification [25].

Results

Three separate comparisons were completed for the 14 participants with cuffed tracheostomy tubes: (1) cuff inflated versus cuff deflated, (2) cuff inflated versus one-way valve, and (3) cuff deflated versus one-way valve. Only one comparison was completed for the four individuals with cuffless tracheostomy tubes: no one-way valve versus one-way valve. The 95% level of confidence was selected as statistically significant.

Reliability

Repeated viewing of the videotapes were allowed so that each judge could make the most accurate ratings possible. Neither judge was aware of tracheostomy tube occlusion status. The two judges independently rated the presence or absence of aspiration, timing of aspiration, severity of penetration/aspiration, amount of oral and pharyngeal residue, and all swallow duration measures. Each judge was blinded to the ratings of the other judge.

In order to determine intrajudge reliability, one judge reviewed 20% of the videotapes, which were randomly selected, twice. This judge was unaware of ratings from the previous viewing.

Pearson's product moment correlations were computed for all duration measures. Kendall's tau correlations were computed for scores on the penetration–aspiration scale and for oropharyngeal residue. Correlations for interjudge reliability ranged from 0.915 to 1.000. Correlations for intrajudge reliability ranged from 0.906 to 1.000.

Cuff Inflation versus Cuff Deflation

Penetration–Aspiration Scale

The number of penetration and aspiration occurrences for liquid and pureed boluses are presented in Tables 2 and 3, respectively. The majority of aspiration occurrences were silent (the participant made no effort to expel the aspirated material from the airway) and during the swallow. The mean score on the penetration–aspiration scale for the liquid bolus was 6.571 (SE = 0.462) for the cuff-inflated condition and 6.321 (SE = 0.741) for the cuff-deflated condition. The mean score for the pureed bolus was 2.623 (SE = 0.745) for the cuff-inflated condition and 2.181 (SE = 0.544) for the cuff-deflated condition. A 2 · 2 (condition · bolus) repeated-measures analysis of variance (ANOVA) indicated a significant effect of bolus [$F(1,13) = 48.497$, $p < 0.001$]. Scores on the penetration–aspiration scale were significantly lower (better) for the pureed bolus than for the liquid bolus. There was no significant effect of condition.

Swallow Duration Measures

Means were derived for all seven duration measures. A two-factor (condition and bolus) doubly multivariate repeated-measures ANOVA revealed a significant effect for condition [$F(7,7) = 3.852$, $p = 0.048$]. Univariate testing revealed pharyngeal transit duration (PTD) [$F(1,13) = 5.487$, $p = 0.036$] and duration of hyoid maximum anterior excursion (DOHMAE) [$F(1,13) = 4.719$, $p = 0.049$] were significantly longer for the cuff-deflated condition than for the cuff-inflated condition. Duration of cricopharyngeal opening (DOCPO) was significantly shorter for the cuff-deflated condition than for the cuff-inflated condition [$F(1,13) = 4.719$, $p = 0.005$]. There was no significant effect of bolus.

Hyolaryngeal Excursion

Mean maximum laryngeal elevation for the liquid bolus was 9.853 mm (SE = 0.763) for the cuff-inflated condition and 9.656 mm (SE = 0.944) for the cuff-deflated condition. Mean maximum laryngeal elevation for the pureed bolus was 9.023 mm (SE = 0.717) for the cuff-inflated condition and 8.942 mm (SE = 0.408) for the cuff-deflated condition. A 2 · 2 (condition · bolus) univariate repeated-measures ANOVA revealed no significant effect of condition.

Mean maximum hyoid anterior excursion for the liquid bolus was 11.350 mm (SE = 0.635) for the cuff-inflated condition and 12.076 mm (SE = 1.002) for the cuff-deflated condition. Mean maximum hyoid anterior excursion for the pureed bolus was 9.314 mm (SE = 0.908) for the cuff-inflated condition and 11.055 mm (SE = 0.642) for the cuff-deflated condition. A 2 · 2 (condition · bolus) univariate repeated-measures ANOVA revealed a significant main effect for condition [$F(1,13) = 7.960$, $p = 0.014$]. Mean maximum hyoid anterior movement was significantly greater for the cuff-deflated condition than for the cuff-inflated condition. In addition, there was a significant effect of bolus [$F(1,13) = 32.379$, $p < 0.001$]. Hyoid anterior movement was significantly greater for the liquid bolus than for the pureed bolus.

Residue

A two-factor (condition and bolus) doubly multivariate repeated-measures ANOVA revealed no significant effect of condition or bolus.

Cuff Inflation Versus One-Way Tracheostomy Speaking Valve Placement

Penetration–Aspiration Scale

The number of penetration and aspiration occurrences for liquid and pureed boluses are presented in Tables 2 and 3, respectively. As with the previous analysis, the majority of aspiration occurrences were silent and during the swallow.

Table 2. Penetration–aspiration of liquid bolus

	Cuff inflated		Cuff deflated		One-way valve	
Subject no.	1st bolus	2nd bolus	1st bolus	2nd bolus	1st bolus	2nd bolus
1	A[a]	—	A	—	No P[b]-A	No P-A
2	A	A	P	—	No P-A	No P-A
3	A	P	No P-A	No P-A	No P-A	No P-A
4	A	A	A	—	P	—
5	A	A	A	—	No P-A	—
6	A	—	P	A	A	—
7	A	A	A	A	No P-A	No P-A
8	A	—	A	—	A	—
9	A	—	A	A	P	No P-A
10	A	—	A	—	P	No P-A
11	A	P	No P-A	No P-A	No P-A	No P-A
12	A	P	A	A	No P-A	No P-A
13	A	P	A	—	A	A
14	A	A	A	A	No P-A	No P-A
15	N/A	N/A	No P-A	No P-A	No P-A	No P-A
16	N/A	N/A	A	A	No P-A	No P-A
17	N/A	N/A	A	A	No P-A	No P-A
18	N/A	N/A	A	A	No P-A	No P-A

[a]A = Aspiration.
[b]P = Penetration.
— = Participant did not complete this trial.

The mean score on the penetration–aspiration scale for the liquid bolus was 6.571 (SE = 0.462) for the cuff-inflated condition and 3.056 (SE = 0.639) for the one-way valve condition. The mean score on the penetration–aspiration scale for the pureed bolus was 2.623 (SE = 0.745) for the cuff-inflated condition and 2.585 (SE = 0.705) for the one-way valve condition. A 2 · 2 (condition · bolus) repeated-measures ANOVA revealed that scores on the penetration–aspiration scale were significantly lower for the one-way valve condition than for the cuff-inflated condition [$F(1,13) = 16.345$, $p = 0.001$]. In addition, scores were significantly lower for the pureed bolus than for the liquid bolus [$F(1,13) = 56.254$, $p < 0.001$].

Swallow Duration Measures

Means were derived for all seven duration measures. A two-factor (condition and bolus) doubly multivariate repeated-measures ANOVA revealed no significant effect for condition or for bolus.

Hyolaryngeal Excursion

Mean maximum laryngeal elevation for the liquid bolus was 9.853 mm (SE = 0.763) for the cuff-inflated condition and 8.493 mm (SE = 0.718) for the one-way valve condition. Mean maximum laryngeal elevation for the pureed bolus was 9.023 mm (SE = 0.717) for the cuff-inflated condition and 9.569 mm (SE = 0.718) for the one-way valve condition. A 2 · 2 (condition · bolus) univariate repeated-measures ANOVA revealed no significant effect of condition or bolus.

Mean maximum hyoid anterior movement for the liquid bolus was 11.350 mm (SE = 0.635) for the cuff-inflated condition and 10.736 mm (SE = 0.866) for the one-way valve condition. Mean maximum hyoid anterior movement for the pureed bolus was 9.314 mm (SE = 0.908) for the cuff-inflated condition and 11.465 mm (SE = 0.734) for the one-way valve condition. A 2 · 2 (condition · bolus) univariate repeated-measures ANOVA indicated no significant effect of condition. There was a significant effect for bolus [$F(1,13) = 4.955$, $p = 0.044$]. Maximum hyoid anterior movement was significantly greater for the liquid bolus than for the pureed bolus.

Residue

A two-factor (condition and bolus) doubly multivariate repeated-measures ANOVA revealed a significant effect of condition [$F(5,9) = 10.280$, $p = 0.002$]. Specifically, residue in the oral cavity

Table 3. Penetration–aspiration of pureed bolus

	Cuff inflated		Cuff deflated		One-way valve	
Subject no.	1st bolus	2nd bolus	1st bolus	2nd bolus	1st bolus	2nd bolus
1	A[a]	—	No P[b]-A	No P-A	No P-A	No P-A
2	P	P	No P-A	No P-A	No P-A	No P-A
3	No P-A	No P-A	No P-A	No P-A	No P-A	P
4	A	—	A	—	P	—
5	P	—	A	—	P	—
6	P	P	P	A	A	—
7	No P-A	No P-A	P	A	No P-A	No P-A
8	A	—	A	—	A	—
9	No P-A	No P-A	No P-A	No P-A	No P-A	No P-A
10	No P-A	No P-A	No P-A	No P-A	No P-A	No P-A
11	No P-A	No P-A	No P-A	No P-A	No P-A	No P-A
12	No P-A	No P-A	No P-A	No P-A	No P-A	No P-A
13	No P-A	No P-A	No P-A	No P-A	No P-A	No P-A
14	No P-A	No P-A	No P-A	No P-A	No P-A	No P-A
15	N/A	N/A	No P-A	No P-A	No P-A	No P-A
16	N/A	N/A	A	—	A	—
17	N/A	N/A	No P-A	No P-A	No P-A	No P-A
18	N/A	N/A	No P-A	No P-A	No P-A	No P-A

[a]A = Aspiration.
[b]P = Penetration.
— = Participant did not complete this trial.

[$F(1,13) = 13.760$, $p = 0.003$], on the posterior pharyngeal wall [$F(1,13) = 5.799$, $p = 0.032$], and at the cricopharyngeus [$F(1,13) = 5.452$, $p = 0.036$] was significantly greater for the one-way valve condition than for the cuff-inflated condition. Bolus type also had a significant effect on residue [$F(5,9) = 4.207$, $p = 0.030$]. Residue in the valleculae was significantly greater for the pureed bolus than for the liquid bolus [$F(1,13) = 14.694$, $p = 0.002$].

No Cuff or Cuff Deflation Versus One-way Tracheostomy Speaking Valve Placement

Penetration–Aspiration Scale

The number of penetration and aspiration occurrences for the liquid and pureed boluses are presented in Tables 2 and 3, respectively. The mean score on the penetration–aspiration scale for the liquid bolus was 6.111 (SE = 0.667) for the no cuff or cuff-deflated condition and 3.056 (SE = 0.639) for the one-way valve condition. The mean score for the pureed bolus was 2.366 (SE = 0.542) for the no cuff or cuff-deflated condition and 2.585 (SE = 0.705) for the one-way valve condition. A 2 · 2 (condition · bolus) repeated-measures ANOVA revealed a significant effect of condition [$F(1,17) = 8.042$, $p = 0.011$] and bolus [$F(1,17) = 8.112$, $p = 0.011$]. There was also a significant interaction between condition and bolus [$F(1,17) = 8.834$, $p = 0.009$]. To further examine the interaction, a repeated-measures ANOVA was performed for each bolus type under each condition. Results for the liquid bolus revealed a significant effect of condition [$F(1,17) = 18.204$, $p = 0.001$]. Scores were significantly lower for the one-way valve condition than for the no cuff or cuff-deflated condition. There was no effect of condition for the pureed bolus.

Swallow Duration Measures

Means were derived for all seven duration measures. A two-factor (condition and bolus) doubly multivariate repeated-measures ANOVA revealed no significant effect of condition.

Hyolaryngeal Excursion

Mean maximum laryngeal elevation for the liquid bolus was 9.224 mm (SE = 0.763) for the no cuff or cuff-deflated condition and 8.493 mm (SE = 0.718) for the one-way valve condition. Mean maximum laryngeal elevation for the pureed bolus was 8.840 mm (SE = 0.489) for the no cuff or cuff-deflated condition and 9.569 mm (SE = 0.718) for the one-way valve condition. A 2 · 2 (condition · bolus) univariate repeated-measures ANOVA revealed no significant effect of condition.

Mean maximum hyoid anterior movement for the liquid bolus was 11.671 mm (SE = 0.834) for the no cuff or cuff-deflated condition and 10.736 mm (SE = 0.866) for the one-way valve condition. Mean maximum hyoid anterior movement for the pureed bolus was 10.654 mm (SE = 0.570) for the no cuff or cuff-deflated condition and 11.465 mm (SE = 0.734) for the one-way valve condition. A 2 · 2 (condition · bolus) univariate repeated-measures ANOVA revealed no significant effect of condition.

Residue

A two-factor (condition and bolus) doubly multivariate repeated-measures ANOVA revealed no significant effect of condition.

Discussion

We found that cuff status, i.e., inflated versus deflated, had no effect on penetration or aspiration. However, one-way valve placement significantly reduced scores on the penetration–aspiration scale for the liquid bolus when compared to the cuff-inflated and cuff-deflated conditions. Most patients (8 of 10) who aspirated thin liquids with their cuffs inflated or deflated were able to safely take thin liquids when the one-way valve was in place.

Deflating the Cuff

Results indicate that cuff deflation did not reduce incidence or severity of aspiration compared with the cuffed or one-way valve conditions. One reason that the deflated cuff did not improve aspiration status is that subglottal pressure cannot be restored by cuff deflation alone. Decreased subglottal air pressure has been identified as a primary mechanism responsible for aspiration in tracheostomized patients [26]. It has been demonstrated that subglottal pressure restoration can be improved in the presence of a one-way valve. Thus, lack of subglottal pressure restoration may contribute to the lack of significant effect in aspiration severity in the deflated cuff condition.

Another reason that cuff deflation alone did not reduce aspiration severity is because both inspiratory and expiratory air is largely exchanged via the tracheostomy tube bypassing the upper airway. It has been demonstrated that the adductor vocal fold reflex sensitivity decreases in the presence of tracheostomy tubes [8], presumably because of the lack of airflow through the glottis. Thus, decreased airflow through the glottis in the deflated cuff condition may exacerbate the decreased adductor vocal fold reflex, negatively impacting swallowing and airway protection.

To determine if deflating the cuff affected specific biomechanical aspects of the swallow, we analyzed a number of swallow duration measures, extent of hyolaryngeal excursion, and the amount of oropharyngeal residue. Cuff deflation significantly increased two swallow duration measures: pharyngeal transit duration and duration of hyoid maximum anterior excursion. However, duration of cricopharyngeal opening was significantly reduced when the cuff was deflated. Reasons for this are difficult to discern. The presence of a nasogastric tube is thought to interfere with relaxation of the cricopharyngeal sphincter [30]. All but one of our participants had a nasogastric tube in place at the time of his or her swallow examination. Thus, the presence of a nasogastric tube may account for the reduction in duration of cricopharyngeal opening that was seen in our patient population. We did not record size of nasogastric tubes in our participants. Thus, we cannot speculate on the specific effects of nasogastric tube placement in our patient population.

An increased extent of hyoid maximum anterior movement (mm) was observed in conjunction with cuff deflation. However, no significant increase in maximum laryngeal elevation was noted. Thus, cuff deflation, based on our sample, appears to produce a greater deflation effect on the hyoid than the thyroid cartilage.

No effects of cuff deflation were observed on pharyngeal residue, even though one might expect to observe an increase in pyriform residue in association with decreased duration of cricopharyngeal opening. Perhaps the extent of cricopharyngeal opening allowed for, or compensated for, any reduction in duration of opening.

One-Way Valve Use

Our results indicate that the one-way valve significantly reduced the incidence and severity of aspiration of thin liquids as measured by an 8-point penetration–aspiration scale. Eight of 10 participants who aspirated the liquid bolus with the cuff inflated and deflated did not aspirate when the one-way valve was placed.

A possible reason for the reduction in incidence of aspiration is that one-way valve placement may restore subglottal air pressure that is lost when

tracheostomy tube is in place [9,10]. A reduction in subglottal air pressure may be the primary mechanism responsible for aspiration in tracheostomized patients [26]. Gross et al. [9] found that one-way valve placement results in a significant increase in subglottal air pressure. We did not measure subglottal air pressure in the current study. Measurement of subglottal air pressure in our subject population could have provided greater insight into the differences observed.

Our findings indicate that one-way valve placement resulted in an increased incidence of penetration in conjunction with decreased incidence of aspiration. By allowing air to flow through the upper airway, one-way valve placement may improve laryngeal sensation. Improved sensation might result in a better ability to expel material, either through throat clearing or coughing, from the laryngeal vestibule. Perhaps patients who penetrate while wearing the valve are able to sense material when it enters the laryngeal vestibule and prevent material from falling below the vocal folds. The effect of valve placement on laryngeal sensation needs further study.

In an effort to determine specific effects of one-way valve usage on swallow function, seven swallow duration measures and hyolaryngeal movement were examined. Our results indicate that one-way valve placement did not significantly affect any of the swallow duration measures or extent of hyolaryngeal movement. Thus, the mechanism by which one-way valve placement improves swallow safety remains unclear.

When compared with the cuff-inflated condition, use of the one-way valve resulted in an increase in oral residue, posterior pharyngeal wall residue, and cricopharyngeal residue. This finding is clinically important because patients may be placed at an increased risk of post swallow aspiration while wearing a one-way valve. Previous research [14] reported that tracheostomy tube occlusion reduces duration of tongue base contact to the posterior pharyngeal wall. Placement of a one-way valve may have similar effects. We did not analyze tongue base retraction during this study.

Three of the seven participants in this study who aspirated the pureed consistency without the one-way valve did not aspirate with the one-way valve in place. Again, one could speculate that by allowing air to flow through the upper airway, one-way valve placement might improve laryngeal and pharyngeal sensation, thus reducing the risk of aspiration even when more of the bolus is present in the pharynx. Further research is needed, as few of our participants aspirated on thicker consistencies.

Conclusions and Clinical Implications

Data indicate that patients who are able to tolerate cuff deflation and one-way valve placement may benefit from eating with a one-way valve in place. Specifically, tracheostomized patients who are unable to tolerate thin liquids may be able to safely take thin liquids when the valve is in place. Use of the valve will not always improve swallow physiology, and one must consider the potential for exacerbating oral and pharyngeal residue. Thus, clinicians who complete videofluoroscopic swallow evaluations with tracheostomized patients should include several bolus presentations with the one-way valve in place before making any decisions regarding the use of the valve as a means of reducing aspiration.

Future Research

To better determine the effects of tracheostomy tubes on swallowing physiology, three areas of future research are suggested. First, the effect of the one-way valve on pharyngeal and laryngeal sensitivity needs to be assessed. Second, determining the effects of one-way valve placement on subglottal pressure might elucidate the effects of valve placement on penetration/aspiration. In the current study, aspiration was most frequently noted with thin liquids. We observed an increase in residue when the one-way valve was in place. It is possible that one-way valve placement may not have as significant an effect on aspiration with patients who aspirate pureed textures. Previous research has indicated that this is the case [17]. Future research should also examine the effects of the one-way valve on larger numbers of participants who aspirate thicker consistencies.

By examining these three areas, perhaps we can gain a more realistic picture of how one-way valve placement affects swallow physiology.

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