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Dysphagia

Swallowing Physiology of Toddlers with Long-Term Tracheostomies: A Preliminary Study

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Abstract. This study investigated the swallowing physiology of toddler-aged patients with long-term tracheostomies. Structural movements and motility of the pharyngeal stage of swallowing were studied in four toddlers ranging in age from 1:2 (years:months) to 2:9 with long-term tracheostomies. A patient aged 1:2 years with no tracheostomy served as a toddler model for comparison. Videofluoroscopic recordings of the patients' liquid and puree bolus swallows were analyzed for a) onset times for pharyngeal stage events, laryngeal vestibule closure, and tracheostomy tube movement; b) timeliness of swallow response initiation; and c) pharyngeal transport function. Results found differences in timing of pharyngeal stage movements between the tracheostomized patients and the patient with no tracheostomy. Laryngeal vestibule closure occurred before or within the same 0.033-s video frame as onset of upper esophageal sphincter (UES) opening in the patient with no tracheostomy, but occurred 0.033–.099 s after onset of UES opening in the tracheostomized patients. The time line required to close the laryngeal vestibule once the arytenoids began their anterior movement was longer in the tracheostomized patients than in the patient with no tracheostomy and was associated with laryngeal penetration. The patient with no tracheostomy displayed superior excursion of the arytenoid and epiglottis during the swallowing; the tracheostomized patients did not. No association was found between onset of tracheostomy tube movement and laryngeal vestibule closure. Delayed swallow response initiation was observed across tracheostomized patients at a mean frequency of 45% with associated penetration. Pharyngeal dysmotility was not observed. Findings supported the concept that long-term tracheostomy in toddler-aged patients affects swallowing physiology.

Key words: Pediatric tracheostomy — Swallowing — Dysphagia — Videofluoroscopy — Deglutition — Deglutition disorders

Historically, tracheostomy in pediatric patients was used as a life-saving measure and for children with end-stage disease. Because of advances in medicine and technology, tracheostomy is now used earlier to prevent respiratory failure and pulmonary disease and to improve quality of life [1]. The increased number of tracheostomies in patients under the age of 2 years supports this statement [2,3], with a yearly increase in pediatric tracheostomies estimated as high as 2600 [4].

The effect of tracheostomy on laryngeal function as it relates to phonation is well-known and readily understood. Young pediatric patients with tracheostomy, especially those placed during the prelinguistic stage of development, display language delays and speech deficits during and after cannulation [5–9]. Tracheostomy in adult patients has been found to affect not only phonation but also swallowing physiology with the primary effect on the pharyngeal stage [10]. Pharyngeal stage swallowing deficits attributed to tracheostomy in adult patients include altered protective glottic closure response [11], diminished elevation and anterior rotation of the larynx [12], delayed swallow response initiation [13], shortened duration of glottic closure [14], and loss of subglottic air pressure [15].

Swallowing problems in infants and young children with tracheostomies have been recognized in the literature [3,4,16–19], but there are no published research studies of swallowing physiology addressing this patient population. Underlying medical conditions and reasons

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for tracheostomy confound studies of swallowing physiology in patients with tracheostomies who are in their early, developmental years. However, Rosingh and Peek [20] reported 91% of their 36 tracheostomized infant patients had swallowing disorders with only half attributed to underlying neurological or anatomic deficits. The purpose of this preliminary study was to investigate the timing of structural movements and motility of the pharyngeal stage of swallowing in a small, select group of toddler-aged patients whose larynges were perturbed by long-term tracheostomy cannulas.

Methods and Materials

Patients

Patients included 4 toddlers, 1 female and 3 males, ages 1:2 (years: months), 1:3, 2:2, and 2:9, who had long-term tracheostomies. Average time since cannulation was 15 months (range = 11–20 months) (Table 1). Another patient aged 1:2 years who had no tracheostomy served as our toddler model of swallowing physiology. The tracheostomized patients in our study were selected from a larger pool of pediatric patients with tracheostomies followed prospectively through the Little Tykes with Trachs Program, Department of Otolaryngology, Montefiore Medical Center, Bronx, NY, and had been referred to the program for determining their candidacy for use of the Passy Muir valve (Passy Muir, Inc., Irvine, CA). The goal of subject selection was to rule out, as best as possible, pharyngeal stage dysphagia secondary to the patients' primary etiologies and indication for tracheostomy (Table 1). Patient A aged 1:2 years and Patient B aged 1:3 years had tracheostomies placed for prolonged intubation after corrective cardiac surgery. They were weaned from mechanical ventilation at ages 5 and 13 months, respectively. Patient C aged 2:2 years required tracheostomy to provide an airway because of vocal cord paresis after corrective cardiac surgery. Resolution of vocal cord paresis was confirmed by direct laryngoscopy at age 1:10 years. Patient D aged 2:9 years had a tracheostomy placed to provide an airway because of obstructive sleep apnea. The latter was secondary to sphincteric constriction of the pharynx during vigorous respiration which subsequently resolved as confirmed by nasopharyngoscopy at age 1:11 years. The tracheostomized patients were neither self-occluding nor wearing any device on the hub of their tracheostomy tubes at the time of this study. Patients A and B had no audible phonation with or without occlusion of the cannula by the examiner; patients C and D had scant, intermittent audible phonation without occlusion of the cannula. The tracheostomized patients used gestures to communicate their needs and wants, with patients B, C, and D also having a small corpus of manual signs. Gross motor skills of the tracheostomized patients included head and trunk control, independent sitting, and either cruising or walking. The problem-solving skills [21] of patients A and B were at 1 year developmentally; patients C and D demonstrated problem-solving skills at 1:9 and 2:3 years, respectively. None of the tracheostomized patients were diagnosed with mental retardation, cerebral palsy, or the Robin sequence.

The patient with no tracheostomy, who served as our toddler model, had been referred to the Pediatric Swallowing Program, Otolaryngology Faculty Practice, Montefiore Medical Center, as a component of her comprehensive workup through the Department of Pediatrics to explain three months of diminished oral intake with refusal-to-feed behaviors. This patient's bone age was within normal limits as were her neurological and linguistic levels. Her feeding problem was found to be environmentally based and was subsequently remediated.

All 5 patients were oral-only feeders on bottle feeds of thin liquids, spoon feeds of purees, soft chewables, and finger foods in the home. The parents reported no difficulties swallowing liquid from a bottle or puree from a spoon, but the tracheostomized patients occasionally gagged on chewables. The tracheostomized patients' noninstrumental clinical swallowing examinations were remarkable for absent or severely reduced laryngeal movement palpated on bolus swallows, secretion build up with accumulation at the level of the larynx and trachea on intake of oral feeds, and no reflexive cough to clear except when suctioned through the cannula.

Videofluoroscopic Swallowing Procedure

All patients were examined under videofluoroscopy. Half-inch VHS video recordings of the fluoroscopic images of the oral and pharyngeal stages of swallowing were captured in the lateral projection using a Philips Super CP80 x-ray generator with an XR50A multiscan wideband imaging recorder, image intensifier (7 inch mode), and XTV6 camera system (1024 line rate). Patients were seated upright in a Tumble Form Seat (Preston Company, Jackson, MI) with padding under the buttocks and spine as needed and head–cervical spine angled in a neutral position. They were offered thin and thick liquid from a bottle and cup, thin and thick puree from a syringe and spoon, and chewable solid bolus consistencies. Compliance for bolus consistencies and containers varied across patients. All patients accepted low-density liquid barium (E-Z-EM Co., Westbury, NY) from a bottle with a crosscut nipple (Mead Johnson, Evansville, IN) and 1-, 1.5-, or 2-cc thin puree boluses placed in the oral cavity using a 3-cc syringe. Thin puree was prepared in accordance with Marquis and Pressman [22], i.e., 2 oz of Stage II puree apple sauce (H.J. Heinz Co., Pittsburgh, PA) to 1 tbsp of powdered barium sulfate (E-Z-EM Co., Westbury, NY).

Data Analysis

All liquid swallows from a bottle and puree swallows placed with a syringe that were completely visualized on the video recordings were subjected to in-depth analysis using the Kay Computerized Swallowing Video Analysis System (Kay Elemetrics Corp., Lincoln Park, NJ) and a Panasonic video playback system (AG-7300 VCR, AG-CT2010 monitor) coupled to a F21 Smpte time code generator and Panasonic remote (AG-A600) (Matsushita Electric Industrial Co, Ltd., Japan). These two integrated systems allowed for analysis in real time, slow motion, and frame by frame (30 frames/s; 1 frame = 0.033 s) with image enhancement and derivation of objective timing measures. In addition, the Kay system provided annotation, storage, and archiving of the digitized fluoroscopic images.

The patients' swallows were analyzed for timeliness of initiation, with onset of swallow initiation marked by (first frame) soft palate to posterior pharyngeal wall contact. The swallow response for puree bolus swallows was considered delayed when it was initiated after the bolus head had passed the point where the mandible crosses the base of tongue [23]. For liquid bolus swallows sucked from a bottle, the swallow response was considered delayed when it was initiated after the bolus head passed the valleculae [24].

Temporal measures were obtained from each of the 5 patients' videofluoroscopic recordings for (1) a thin puree bolus swallow initiated without delay and (2) a liquid bolus swallow from a bottle/nipple with a suck:swallow ratio of 2:1 initiated without delay. Puree bolus size was 1–2 cc; liquid bolus volume could not be determined. Selection of swallows for in-depth temporal analysis was based on clarity of

Table 1. Characteristics of patients with tracheostomies

Patient	Gender	Age at cannulation (yrs:mos)	Age at testing[a] (yrs:mos)	Primary etiologies	Primary indication for tracheostomy
A	F	0:2	1:2	Congenital heart disease Bronchomalacia	Prolonged ventilation[c]
B	M	0:4	1:3	Congenital heart disease Tracheobronchomalacia	Prolonged ventilation[c]
C	M	0:10	2:2	Congenital heart disease Vocal cord paresis[b]	Provide an airway
D	M	1:1	2:9	Craniofacial disorder Obstructive sleep apnea[b]	Provide an airway

[a]Chronological age at time of fluoroscopy.
[b]Resolved at time of fluoroscopy.
[c]Weaned from mechanical ventilation and oxygen at time of fluoroscopy.

visualization of the oral, pharyngeal, and laryngeal structures and their movements; the tracheostomy tube and its movement; and the cervical spine, with maintenance of head neutral positioning without extraneous movements. Onset time of movements of airway closure at the level of the laryngeal vestibule and UES opening in relation to velopharyngeal closure, and location of the bolus head at points of supraglottic airway closure and UES opening in relation to movement of the cannula were targeted.

Pharyngeal stage motility was described using Leopold and Kagel's [24] videofluoroscopic descriptors of pharyngeal transport function which divide the pharynx into the anterior segment (laryngeal and epiglottic motility) and the posterior segment (pharyngeal constrictor motility).

Data were subsequently analyzed using visual inspection, descriptive statistics, and nonparametric 1-sample Chi-square and 2-sample Mann–Whitney U tests.

Results

Delayed Swallow Response Initiation

Percentage of occurrence scores for delayed swallow response initiation were calculated for each tracheostomized patient by totaling the number of delayed swallows for both liquid and puree bolus types and dividing by the total number of swallows analyzed ($N = 38$) (Table 2). Seventeen (45%) of the patients' swallows were delayed. Of this number, 14 (82%) were liquid swallows from a bottle and 3 (18%) were puree swallows from a syringe. Penetration, defined as entry of material into the laryngeal vestibule down to, but not below, the level of the true vocal cords [23] (Fig. 1), occurred during 13 (76%) of the delayed swallows. Aspiration, defined as entry of material below the true vocal cords [23], occurred on 1 swallow initiated with delay. The patient with no tracheostomy initiated 1 swallow with delay (7%; $n = 13$) during a period of noncompliance which did not result in airway penetration or aspiration.

The tracheostomized patients also penetrated and aspirated on timely bolus swallows as described below.

Table 2. Tracheostomized patients' percentages of occurrence of delayed swallows and delayed swallows with penetration

Patient	Total No. swallows	Delayed swallow (%)	Delayed swallows with penetration (%)
A	11	18	50
B	07	71	100
C	10	40	25
D	10	60	100[a]
Group mean	10	45%	76%

[a]Includes 1 delayed swallow with aspiration.

Timing of Pharyngeal Stage Movements for Timely Puree Bolus Swallows

Table 3 shows the onset times of pharyngeal stage movements for each patient's selected puree swallow from a syringe initiated without delay. The patient with no tracheostomy displayed velopharyngeal closure followed by superior excursion of the arytenoid and epiglottis, then anterior movement of the arytenoid, with subsequent closure of the laryngeal vestibule and onset of UES opening occurring within the same 0.033-s video frame. Superior movement of the arytenoid and the epiglottis associated with the swallow response commenced 0.033 s after velopharyngeal closure and continued to move superiorly for 0.033 s as the epiglottis began its descent.

The patients with tracheostomies showed velopharyngeal closure followed by onset of anterior movement of the arytenoid, then onset of UES opening. Unlike the patient with no tracheostomy, closure of the laryngeal vestibule occurred 0.033–0.099 s (mean $= 0.049$ s) after UES opening in the patients with tracheostomies. The superior excursion of the arytenoid and epiglottis observed in the patient with no tracheostomy was not seen in the tracheostomized patients. Using the tracheostomized patients' group means, the differences in onset

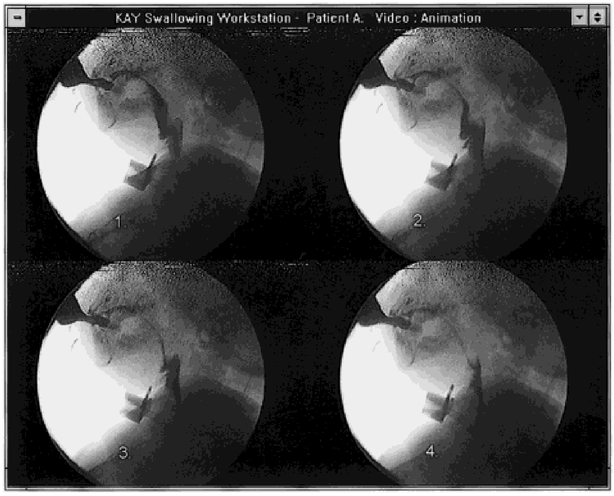

Fig. 1. Lateral view videoprint sequence illustrating penetration of liquid into the laryngeal vestibule to the false vocal cords with clearance of this material as the laryngeal vestibule closes (total time = 0.165).

times of structural movements of the pharyngeal stage of swallow for puree bolus between the patient with no tracheostomy and the patients with tracheostomies were significant ($z = 2.17$; $p = 0.015$).

Timing of Pharyngeal Stage Movements for Timely Liquid Swallows from a Bottle

Table 4 shows onset times of pharyngeal stage movements for each patient's selected liquid swallow from a bottle initiated without delay. The patient with no tracheostomy displayed velopharyngeal closure, followed by superior excursion of the arytenoid and epiglottis, then anterior movement of the arytenoid and closure of the laryngeal vestibule which both occurred within the same 0.033-s video frame. Onset of UES opening occurred after closure of the laryngeal vestibule.

The patients with tracheostomies showed velopharyngeal closure followed by onset of anterior movement of the arytenoid, then onset of UES opening. In contrast to the patient with no tracheostomy, closure of the laryngeal vestibule occurred 0.033–0.099 s (mean = 0.066 s) after UES opening in the patients with tracheostomies. Superior excursion of the arytenoid and the epiglottis observed in the patient with no tracheostomy was not seen in the patients with tracheostomies. Using the tracheostomized patients' group means, the differences in onset times of pharyngeal stage structural movements for timely liquid swallows from a bottle between the patient with no tracheostomy and the patients with tracheostomies were not significant ($z = 1.01036$; $p = 0.156$).

Airway Closure at the Laryngeal Vestibule

According to Logemann et al. [26], closure of the supraglottic airway at the level of the laryngeal vestibule during swallowing involves movement of the epiglottis and the arytenoid to the epiglottic base. For the tracheostomized patients' selected liquid swallows from a bottle initiated without delay (Table 4), onset of arytenoid anterior movement and onset of closure of the laryngeal vestibule occurred within the same 0.033-s video frame for the patient with no tracheostomy. In contrast, the time from onset of arytenoid anterior movement to onset of closure of the laryngeal vestibule ranged from 0.066 to 0.231 s (mean = 0.157 s) for the patients with tracheostomies. Liquid material penetrated the laryngeal vestibule during the swallow of all 4 tracheostomized patients with 1 patient silently aspirating a small amount of this penetrated material. Penetrated material was cleared from the supraglottic airways of the tracheostomized patients as closure of the laryngeal vestibule was achieved (Fig. 1). The patient with no tracheostomy showed no laryngeal penetration or aspiration on liquid swallows.

For the patients' selected puree swallows from a syringe initiated without delay (Table 3), the time from onset of arytenoid anterior movement to onset of closure of the laryngeal vestibule was 0.033 s for the patient with no tracheostomy, and ranged from 0.066 to 0.264 s (mean = 0.124 s) for the patients with tracheostomies. The patient with no tracheostomy did not penetrate or aspirate on puree bolus swallows, whereas 2 of the 4 tracheostomized patients penetrated into the laryngeal vestibule during the swallow, although none of them aspirated. Penetrated material was cleared from the airway with closure of the laryngeal vestibule.

Therefore, when we looked across the two bolus types, we found that the supraglottic airways of the patients with tracheostomies closed slower than that of the patient with no tracheostomy, and the time delay to closure of the laryngeal vestibule was concordant for laryngeal penetration and aspiration (χ^2 [3] = 12, $p = 0.007$).

Tracheostomy Tube Movement Associated with the Swallow

Tracheostomy tube movement was studied because external movement of the tracheostomy tube hub and neck flange is frequently used as a sign of laryngeal movement associated with the swallow response on noninstrumental clinical swallowing examination of patients with tracheostomies. Temporal analysis showed that airway closure at the level of the laryngeal vestibule occurred before onset of tracheostomy tube movement in 57% of

Table 3. Onset times[a] of pharyngeal stage movements for the patients' selected puree bolus swallows[b]

Movements[c]	No tracheostomy patient	Tracheostomy patients A	B	C	D	Mean	SD
Velopharyngeal closure	0.000	0.000	0.000	0.000	0.000		
Superior movement of arytenoid, epiglottis	0.033	n[d]	n	n	n		
Bolus head enters hypopharynx	0.066	0.099	0.033	0.231	0.198	0.140	0.09
Anterior arytenoid movement	0.099	0.132	0.099	0.264	0.198	0.173	0.07
Penetration laryngeal vestibule		n	0.033	n	0.297		
Laryngeal vestibule closed	0.132	0.231	0.165	0.330	0.462	0.297	0.13
UES opening	0.132	0.198	0.132	0.297	0.363	0.248	0.10
Movement of tube		0.264	0.231	0.363	0.396	0.314	0.08
Maximum excursion of tube		0.396	0.297	0.495	0.528	0.429	0.10

[a]Onset time in seconds.
[b]Swallows initiated without delay.
[c]First frame.
[d]n = not observed.

Table 4. Onset times[a] of pharyngeal stage movements for the patients' selected liquid bolus swallows from a bottle[b]

Movements[c]	No tracheostomy patient	Tracheostomy patients A	B	C	D	Mean	SD
Velopharyngeal closure	0.000	0.000	0.000	0.000	0.000		
Superior movement of arytenoid, epiglottis	0.033	n[d]	n	n	n		
Bolus head enters hypopharynx	0.099	0.066	0.000	0.132	0.297	0.124	0.12
Anterior arytenoid movement	0.132	0.066	0.033	0.198	0.297	0.149	0.12
Penetration laryngeal vestibule	n	0.099	0.099	0.231	0.363		
Laryngeal vestibule closed	0.132	0.264	0.165	0.264	0.528	0.305	0.16
UES opening	0.165	0.165	0.132	0.231	0.429	0.239	0.12
Movement of tube		0.198	n	0.330	0.429		
Maximum excursion of tube		0.264	n	0.429	0.528		

[a]Onset time in seconds.
[b]Swallows initiated without delay.
[c]First frame.
[d]n = not observed.

the tracheostomized patients' swallows and after onset of tube movement in 43% of the swallows that displayed tube movement. For timely liquid swallows from a bottle (Table 4), tracheostomy tube movement was observed in 3 of the 4 tracheostomized patients with tube movement secondary to respiratory cycling, confounding measures for one patient. Of the 3 patients with tube movement for liquid swallows, closure of the laryngeal vestibule occurred before onset of tracheostomy tube movement in 1 patient and after onset of tube movement in 2 patients. For timely puree bolus swallows (Table 3), tracheostomy tube movement was observed in all 4 tracheostomized patients, with laryngeal vestibule closure occurring before onset of tracheostomy tube movement in 3 patients and after onset of tracheostomy tube movement in 1 patient. No significant association was found between onset of tracheostomy tube movement and closure of the laryngeal vestibule (χ^2 [3] = 2.71, p = 0.44).

Pharyngeal Motility

Abnormalities of pharyngeal transport and clearance were not observed in the patient with no tracheostomy or in the patients with tracheostomies. None of the patients displayed postswallow residua in the valleculae, pyriform sinuses, or on the epiglottis to indicate anterior segment pharyngeal dysmotility. They did not have stasis within the pharyngeal space or on the posterior pharyngeal wall after the swallow to indicate posterior segment dysmotility. Neither the patient with no tracheostomy nor the patients with tracheostomies showed accumulation of residua on multiple swallows or supraglottic penetration or glottic aspiration after the swallow.

Discussion

It is a generally accepted principle that tracheostomy in adult patients adversely affects swallowing physiology.

It has remained unclear whether the same holds true for tracheostomized pediatric patients who are in their early developmental years. Dysphagia secondary to the young, pediatric patient's primary medical condition confounds our ability to rule out swallowing deficits associated with the tracheostomy itself. The criteria used for patient selection in this study represented an attempt to address this issue. Results did suggest that long-term tracheostomy affects the pharyngeal stage of swallowing in some toddlers. Of course, caution must be exercised with respect to generalization of results. Our sample size was very small and normative swallowing data for this age group were lacking. It will be necessary to replicate this study using larger samples and refinement of patient selection criteria. When feasible, pre- and posttracheostomy placement fluoroscopic swallowing studies should be performed to address the issue of the underlying medical condition confounding results.

Tracheostomy has been shown to adversely affect the larynx during the pharyngeal stage of swallowing in adults, including diminished elevation and anterior rotation of the larynx [12], shortened duration of glottic closure [14], and loss of subglottic air pressure [15]. Although studying toddler-aged pediatric patients under videofluoroscopy poses numerous restrictions and obstacles, insight was gained into a possible laryngeal effect due to long-term tracheostomy in this age group. Superior excursion of the arytenoid and epiglottis during the swallow was observed in our toddler with no tracheostomy. This movement was consistent with longitudinal shortening of the pharynx that occurs during the swallow and with Kahrilas' [27] finding that most of pharyngeal shortening occurs between the valleculae and the superior margin of the arytenoid in adults. Laryngeal elevation is the result of longitudinal pharyngeal shortening [27]. Superior excursion of the arytenoid and epiglottis during the swallow was not observed in our tracheostomized toddlers, thus implicating reduced superior laryngeal excursion secondary to tracheostomy in these young children.

A slowing effect on laryngeal movement due to tracheostomy was also suggested from our findings. Our toddler with no tracheostomy showed laryngeal vestibule closure either before or within the same 0.033-s video frame as onset of UES opening, whereas our tracheostomized toddlers showed laryngeal vestibule closure after onset of UES opening regardless of bolus type. More notably, the time line required to close the laryngeal vestibule once the arytenoids began their anterior movement was longer in our tracheostomized toddlers than in our toddler with no tracheostomy and resulted in laryngeal penetration during the swallow that cleared as the laryngeal vestibule closed. According to Logemann [23], the etiology of laryngeal penetration that occurs during the swallow and clears when the larynx lifts to its full range of motion and closes is a larynx that is moving too slowly.

Delayed swallow response initiation was observed in our 4 toddlers with tracheostomies at varied frequency levels. DeVita and Spierer–Rundback [13] reported delayed initiation of the swallowing response in their ten adult patients with tracheostomies. Delayed initiation of the swallowing response increases the risk of airway contamination because bolus material frequently spills inferior to the hypopharynx during the delay time before the swallow is initiated. This preswallow spillage easily enters the airway as the swallow is initiated and structures begin to move. DeVita and Spierer–Rundback reported laryngeal penetration in their ten adult patients with tracheostomies but did not specify the underlying cause of the penetration. We did confirm laryngeal penetration associated with swallow response delay in our 4 pediatric patients with tracheostomies.

External movement of the tracheostomy tube hub and neck flange is of clinical interest because it is frequently used on noninstrumental clinical examinations of swallowing as a sign of laryngeal movement associated with the swallow response. We did not find a close association between laryngeal vestibule closure and tracheostomy tube movement in our toddlers with tracheostomies; however, we did observe that tube movement appeared to be facilitated by bolus body pressure as the bolus was transported through the hypopharynx and UES. However, this observation could not be validated under fluoroscopy because of the absence of three dimensional imaging (T. Kotz, personal communication).

The tracheostomized toddlers we studied were not referred for swallowing evaluation nor were their parents reporting swallowing difficulties for liquid or puree bolus intake in the home. Their clinical swallowing exams did reveal signs of pharyngeal stage dysfunction implicating laryngeal movement coupled with reduced airway protective reflexive responses and secretion management. The use of videofluoroscopy for direct diagnostic study of swallowing physiology in these tracheostomized toddlers was substantiated by our findings of laryngeal penetration and the etiologies of this supraglottic airway contamination. Clinically, the need for dysphagia treatment as a component of the tracheostomized toddlers' treatment plans was indicated from fluoroscopic findings and was accomplished through the Little Tykes with Trachs Program [28]. In view of the increased number of tracheostomies in patients under the age of 2 years, many of whom reside at home [29], and the overwhelming majority of speech–language pathologists who reported feeling unprepared to serve tracheostomized pediatric patients [30], there is a critical need for continued clinical research studies to expand our knowledge base and clinical protocols in swallowing (re)habilitation for this specialty patient population. Also critical is the need for data related to normal swallowing physiology in pediatric patients at the toddler stage as well as at other stages along the developmental continuum to mature feeding [31].

References

1. Laraya-Cuasay L, Mikkilineni S: Respiratory conditions and care. In: Rosenthal S, Sheppard J, Lotze M (eds): *Dysphagia and the Child with Developmental Disabilities.* San Diego, CA: Singular Publishing Group, 1995, pp 227–252
2. Kenna M, Reilly J, Stool S: Tracheostomy in the preterm infant. *Ann Otol Rhinol Laryngol 96:*68–71, 1987
3. Wetmore R, Handler S, Potsic W: Pediatric tracheostomy experience during the past decade. *Ann Otol Rhinol Laryngol 91:*628–632, 1982
4. Bleile K: Children with long-term tracheostomies. In: Bleile K (ed): *The Care of Children with Long-Term Tracheostomies.* San Diego, CA: Singular Publishing Group, 1993, pp 3–19
5. Kaslon K, Stein R: Chronic pediatric tracheostomy: assessment and implications for habilitation of voice, speech and language in young children. *Int J Pediatr Otorhinolaryngol 9:*165–171, 1985
6. Kaslon K, Grabo D, Ruben R: Voice, speech, and language habilitation in young children without laryngeal function. *Arch Otolaryngol 104:*737–739, 1978
7. Hill B, Singer L: Speech and language development after infant tracheostomy. *J Speech Hear Dis 55:*15–20, 1990
8. Kamen R, Watson B: Effects of long-term tracheostomy on spectral characteristics of vowel production. *J Speech Hear Res 34:*1057–1065, 1991
9. Kertoy M, Guest C, Quart E, Lieh-Lai M: Speech and phonological characteristics of individual children with a history of tracheostomy. *J Speech Hear Res 42:*621–635, 1999
10. Nash M: Swallowing problems in the tracheotomized patient. *Otolaryngol Clin North Am 21:*701–709, 1988
11. Sasaki C, Suzuki M, Horiuchi M, Kirchner J: The effect of tracheostomy on the laryngeal closure reflex. *Laryngoscope 87:*1428–1433, 1977
12. Bonanno P: Swallowing dysfunction after tracheostomy. *Ann Surg 174:*29–33, 1971
13. DeVita M, Spierer-Rundback L: Swallowing disorders in patients with prolonged orotracheal intubation or tracheostomy tubes. *Crit Care Med 18:*1328–1330, 1990
14. Shaker R, Milbrath M, Ren J, Campbell B, Toohill R, Hogan W: Deglutitive aspiration in patients with tracheostomy: Effect of tracheostomy on the duration of vocal cord closure. *Gastroenterology 108:*1357–1360, 1995
15. Eibling D, Gross R: Subglottic air pressure: a key component of swallowing efficiency. *Ann Otol Rhinol Laryngol 105:*253–258, 1996
16. Prescott C, Vanlierde M: Tracheostomy in children—The Red Cross War Memorial Children's Hospital Experience 1980–1985. *Int J Pediatr Otorhinolaryngol 17:*97–107, 1989
17. Simon B, McGowan J: Tracheostomy in young children: Implications for assessment and treatment of communication and feeding disorders. *Inf Young Children 1:*1–9, 1989
18. Brodsky L, Volk M: The airway and swallowing. In: Arvedson J, Brodsky L (eds): *Pediatric Swallowing and Feeding: Assessment and Management.* San Diego, CA: Singular Publishing Group, 1993, pp 93–122
19. Arvedson J, Lefton-Greif M: *Pediatric Videofluoroscopic Swallow Studies.* San Antonio, TX: Communication Skill Builders, 1998
20. Rosingh H, Peek S: Swallowing and speech in infants following tracheostomy. *Acta Otorhinolaryngol Belg 53:*59–63, 1999
21. Bangs T: *Birth to Three Checklist of Learning and Language Behavior.* Allen, TX: Teaching Resources, 1986
22. Marquis J, Pressman H: Radiologic assessment of pediatric swallowing. In: Rosenthal S, Sheppard J, Lotze M (eds): *Dysphagia and the Child with Developmental Disabilities.* San Diego, CA: Singular Publishing Group, 1995, pp 189–207
23. Logemann J: *Manual for the Videofluorographic Study of Swallowing,* 2nd ed. Austin, TX: Pro-Ed, 1993
24. Kramer S, Eicher P: The evaluation of pediatric feeding abnormalities. *Dysphagia 8:*215–224, 1993
25. Leopold N, Kagel M: Pharyngo-esophageal dysphagia in Parkinson's disease. *Dysphagia 12:*11–18, 1997
26. Logemann J, Kahrilas P, Cheng J, Pauloski B, Gibbons P, Rademaker A, Lin S: Closure mechanisms of laryngeal vestibule during swallow. *Am J Physiol 262:*G338–G344, 1992
27. Kahrilas P: Pharyngeal structure and function. *Dysphagia 8:*303–307, 1993
28. Abraham S: Little tykes with trachs + Passy Muir: airway safety, secretion, and swallow (Abstract). *ASHA 39:*179, 1997
29. Ruben R, Newton L, Jornsay D, Stein R, Chambers H, Liquori J, Lawrence C: Home care of the pediatric patient with a tracheotomy. *Ann Otol Rhinol Laryngol 91:*633–640, 1982
30. Manley S, Frank E, Melvin C: Preparation of speech-language pathologists to provide services to patients with tracheostomy tube: A survey. *Am J Speech Lang Pathol 8:*171–180, 1999
31. Bosma J: Development of feeding. *Clin Nutrition 5:*210–218, 1986