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ORIGINAL ARTICLE

Relationship Between Manometric and Videofluoroscopic Measures of Swallow Function in Healthy Adults and Patients Treated for Head and Neck Cancer with Various Modalities

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Abstract Pharyngeal manometry complements the modified barium swallow with videofluoroscopy (VFS) in diagnosing pressure-related causes of dysphagia. When manometric analysis is not feasible, it would be ideal if pressure information about the swallow could be inferred accurately from the VFS evaluation. Swallowing function was examined using VFS and concurrent manometry in 18 subjects (11 head and neck patients treated with various modalities and 7 healthy adults). Nonparametric univariate and multivariate analyses revealed significant relationships between manometric and fluoroscopic variables. Increases in pressure wave amplitude were significantly correlated with increased duration of tongue base to pharyngeal wall contact, reduced bolus transit times, and oropharyngeal residue. Pharyngeal residue was the most important VFS variable in reflecting pharyngeal pressure measurements. Certain VFS measures were significantly correlated with measures of pressure assessed with manometry. Further research is needed before observations and measures from VFS alone may be deemed sufficient for determining pressure-generation difficulties during the swallow in patients who are unable or unwilling to submit to manometric testing.

Keywords Deglutition · Deglutition disorders · Videofluoroscopy · Manometry · Cancer · Correlation

Advances in technology over the past 20 years have enabled clinicians to use manometry to obtain information about pressures in the pharynx and the functioning of the upper esophageal sphincter (UES) during the swallow [1–4]. The utility of pharyngeal manometry as a routine adjunct to esophageal manometry has been questioned [5]. Nevertheless, a body of research does indicate the usefulness of pharyngeal manometry in clarifying the origin of dysphagia in some patients as well as determining the likelihood of success of cricopharyngeal myotomy [6–9]. The results of pharyngeal manometry are more readily interpreted when performed with simultaneous videofluoroscopy (VFS) during the modified barium swallow procedure [10, 11]. With fluoroscopic confirmation of manometric sensor placement during the various stages of the swallow, the observed pressure measurements can be properly attributed as prebolus pressures, intrabolus pressures, and pharyngeal bolus-driving pressures.

Despite its utility in confirming disorders of the UES or pharyngeal constriction, the availability of pharyngeal manometry is limited in some regions [12, 13]. In addition, there are patients who may refuse manometry, such as

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those with severe mucositis after treatment for cancer of the head and neck. Mucositis is the painful inflammation and ulceration of the mucous membranes lining the digestive tract, usually an adverse effect of chemotherapy or radiotherapy. As many as 80% of patients with cancers of the head and neck who are treated with these modalities will experience mucositis as some point during their treatment and it can persist for several months after treatment completion [14]. Attempts to pass a manometer through the pharynx and into the esophagus of a patient with severe mucositis may be very painful.

For situations where manometric analysis is not feasible, it would be ideal if pressure information about the swallow could be inferred from the VFS evaluation. Leonard et al. [14] found a high negative correlation between pharyngeal pressure measured from manometry and a measure of pharyngeal area taken from VFS images; as pharyngeal area decreased, pharyngeal pressure increased. The primary limitation of their study was that the videofluoroscopic and manometric studies were not performed simultaneously. In addition, their measure of pharyngeal area is not readily calculated in the fluoroscopy suite, making clinical application somewhat limited. This study was developed to investigate the relationships between selected pharyngeal manometry measures and videofluoroscopic measures and observations that are more easily collected by the swallowing clinician in the fluoroscopy suite.

Materials and Methods

Subjects

All procedures were approved by the Institutional Review Board for studies involving human subjects at Northwestern University. Eighteen subjects participated in this study: 7 healthy adults and 11 patients treated for cancer of the head and neck. Subject participation was solicited over a period of 2 months; those who agreed to the procedures were enrolled in a consecutive manner. A heterogeneous group of patients and controls were studied in order to increase the likelihood of observing a range of swallow function which would reveal correlations among manometric and videofluoroscopic measures. Of the seven healthy adults, two (29%) were male and five (71%) were female. The healthy adults ranged in age from 48 to 72 years and had an average age of 61 (SD = 8).

Of the 11 patients treated for head and neck cancer, 9 (82%) were male and 2 (18%) were female. The patients ranged in age from 41 to 72 years and had an average age of 62 (SD = 10). Two were treated for tumors of the oral cavity, one for a tumor of the nasopharynx, three for tumors of the oropharynx, one for a tumor of the hypopharynx, two for tumors of the larynx, and two for unknown primary tumors. Most patients (78%) had stage IV disease. Seven patients were treated with chemoradiotherapy for their tumor. Three had primary surgery with postoperative radiotherapy, and one had surgery only. Demographic information for the patients is summarized in Table 1.

Study Protocol

Subjects were examined once using the modified barium swallow procedure with videofluoroscopy and simultaneous manometry. A solid-state manometer with two sensing elements spaced 3 cm apart (Gaeltec Medical Measurement, Hackensack, NJ) was positioned under fluoroscopic guidance, with one microtransducer located at the tongue base and another in the hypopharynx. The metal housing of the strain gauge transducers was asymmetric so

Table 1 Demographic information for 11 patients treated for head and neck cancer

Subject no.	Age	Gender	Treatment type	Site	Stage	Years postreatment
1	57	f	Chemoradiotherapy	Hypopharynx	IV	1.7
2	58	m	Chemoradiotherapy, neck dissection	Unknown primary	IV	3.7
3	63	m	Chemoradiotherapy	Oropharynx	IV	1.0
4	62	f	Chemoradiotherapy	Oropharynx	IV	5.8
5	72	m	Surgery + postop RT	Larynx	IV	10.1
6	41	m	Chemoradiotherapy	Unknown primary	IV	3.8
7	73	m	Surgery + postop RT	Oral cavity	II	6.0
8	58	m	Surgery + postop RT	Oral cavity	III	2.2
9	51	m	Chemoradiotherapy	Oropharynx	IV	3.0
10	70	m	Chemoradiotherapy	Nasopharynx	IV	4.1
11	76	m	Surgery	Larynx	II	2.3

f = female; m = male; postop = postoperative; RT = radiotherapy that the assembly could be rotated under fluoroscopic observation and oriented to record pressures against the posterior pharyngeal wall. Fluoroscopy was also used to assure that the sensors were at the level of the tongue base and hypopharynx at the midpoint of the pharyngeal swallow. During the study, the fluoroscopy tube was focused on the lips anteriorly, the cervical vertebrae posteriorly, the soft palate superiorly, and the bifurcation of the esophagus and airway inferiorly. Fluoroscopic data were recorded on videotape at 30 frames per second. Manometric waveforms were recorded on a computer polygraph set at a sampling frequency of 1000 Hz and processed using Gastromac 3.3.2 software (Neomedix Systems, Sydney, Australia).

The study protocol included two trials each of 1, 3, 5, and 10 ml of barium liquid, 3 cc of barium paste mixed with chocolate pudding, and one quarter of a Lorne Doone shortbread cookie coated with barium paste for contrast. Not all patients were able to swallow two trials of each food consistency at each evaluation point. A patient may have refused to attempt one or both trials of a consistency because of known or suspected difficulty with it; the speech-language pathologist also may have judged it as too great a clinical risk of excessive aspiration to introduce or continue with a specific consistency during the videofluorographic evaluation.

Data Reduction

Manometry tracings were interpreted for the contractile amplitude, duration, and propagation velocity. Research personnel who interpreted the manometric tracings were blinded to the results of the videofluoroscopic recordings. The measures taken from manometric tracings included:

BASE_AMP peak amplitude of pressure wave at the sensor at the base of tongue.
BASE_DUR duration of the pressure wave at the sensor at the base of tongue.
PHAR_AMP peak amplitude of pressure wave at the sensor in the hypopharynx.
PHAR_DUR duration of the pressure wave at the sensor in the hypopharynx.
VELOCITY speed at which the pressure wave propagates from base of tongue to hypopharyngeal sensor.

Though recorded concurrently, videofluoroscopic recordings were analyzed independent of the manometric tracings. Research personnel who analyzed the videofluoroscopic recordings were blinded to the results of the manometric recordings. Videotapes of the swallow studies were viewed in slow motion and frame-by-frame to obtain timing information to compute the following swallowing measures:

Oral Transit Time (OTT): the time it takes the bolus to move through the oral cavity, measured from the first backward movement of the bolus until the head of the bolus passes the point where the ramus of the mandible crosses the tongue base.
Pharyngeal Response Time (RESPONSE): the time required to clear the pharynx, measured from the time of the onset of soft palate elevation until the tail of the bolus leaves the cricopharyngeal region.
Pharyngeal Delay Time (DELAY): the time required to trigger the pharyngeal swallow, measured from the time the head of the bolus passes the ramus of the mandible until the onset of soft palate elevation.
Pharyngeal Transit Time (PTT): the time required for the bolus to move through the pharynx, measured from the time the head of the bolus passes the ramus of the mandible until the tail of the bolus leaves the cricopharyngeal region.
Duration of Tongue Base to Pharyngeal Wall Contact at the level of middle C2 (DURMC2): the duration of contact of the structures.
Duration of Tongue Base to Pharyngeal Wall Contact at the level of inferior C2 (DURIC2): the duration of contact of the structures.
Duration of Tongue Base to Pharyngeal Wall Contact at the level of superior C3 (DURSC3): the duration of contact of the structures.
Vallecula to the Pyriform Sinus (VAL_PS): duration of time it takes for bolus to move from the vallecula to the pyriform sinus.
Approximate Percent Oral Residue (ORES): percent of bolus residue in the oral cavity after the swallow.
Approximate Percent Pharyngeal Residue (PRES): percent of bolus residue in the pharynx after the swallow.

In addition to these measures and observations, several dichotomous measures were taken from videofluoroscopy. Dichotomous measures were chosen because they can be observed quickly by a swallowing clinician during the videofluoroscopic evaluation:

MID_C2 contact occurs between tongue base and posterior pharyngeal wall at the level of mid C2 (Yes/No).
INF_C2 contact occurs between tongue base and posterior pharyngeal wall at the level of inferior C2 (Yes/No).
SUP_C3 contact occurs between tongue base and posterior pharyngeal wall at the level of superior C3 (Yes/No).
C2C3 contact occurs between tongue base and posterior pharyngeal wall at the level of both inferior C2 and superior C3 (Yes/No).

P-VAL presence of bolus residue in the vallecula (Yes/No).

P-PYS presence of bolus residue in the pyriform sinus (Yes/No).

Ten percent of the swallows were randomly selected for reanalysis by the same research technician and a second research technician as a measure of intra- and interjudge reliability. Intrajudge reliability ranged from 0.934 to 0.999, with an average intrajudge reliability of 0.969. Interjudge reliability ranged from 0.917 to 0.989, with an average interjudge reliability of 0.964.

Statistical Analysis

There were five manometric variables and 16 videofluoroscopic (VFS) measures or observations. All manometric variables were continuous. Ten VFS measures were continuous and six were dichotomous. Correlations were calculated on individual swallow data. Analyses were nonparametric so that all analyses used the ranks of each variable. Univariate Spearman correlation coefficients were calculated between each of the six manometric variables and each of the 16 VFS measures and *p* values were reported for these correlations. Using each manometric variable as the dependent variable, stepwise regression identified the VFS measures that were significantly related to that manometric variable at the 0.05 level. Partial Spearman correlation coefficients and their *p* values as well as the multiple correlation coefficient are reported for each VFS variable selected in the multivariate analysis. The multiple correlation coefficient is the correlation between the observed manometric measure and its predicted value from the VFS variables in the regression model. When this coefficient is squared, the resulting number represents the percentage of the variation of a manometric measure that is explained by the combination of VFS measures in the regression model.

Results

Manometric and fluoroscopic measures of swallow function from 18 subjects were subjected to a series of correlation statistics to determine the relationship between the two measurement techniques. A total of 197 swallows were available for statistical analysis. Not all temporal measures or observations could be calculated for every swallow; for example, oral transit time could not be computed for three of the swallows because the anterior oral cavity was out of view at the beginning of the swallow and onset of oral transit could not be viewed. Nevertheless, there were few missing data in this study. Both univariate and multivariate analyses were completed.

Univariate Analysis Results

Table 2 presents the Spearman correlation coefficients and significance levels between the manometric and continuous

Table 2 Spearman correlation coefficients and level of significance for manometric and continuous fluoroscopic measures or observations

Variable	*N*	BASE_AMP		BASE_DUR		PHAR_AMP		PHAR_DUR		VELOCITY	
		Spearman *r*	*p* value	Spearman *r*	*p* value	Spearman *r*	*p* value	Spearman *r*	*p* value	Spearman *r*	*p* value
OTT	194	−0.0091	0.90	0.23	0.0010*	−0.17	0.0205*	0.28	<0.0001*	0.10	0.18
RESP	196	0.051	0.48	0.25	0.0005*	−0.14	0.044*	−0.003	0.97	−0.21	0.0036*
DELAY	194	−0.15	0.039*	0.010	0.89	−0.051	0.48	0.13	0.07	0.14	0.058
PTT	194	−0.12	0.091	0.16	0.023*	−0.16	0.0244*	0.08	0.29	−0.048	0.51
DURMC2	197	0.20	0.0053*	0.32	<0.0001*	0.12	0.09	0.20	0.0052*	0.068	0.34
DURIC2	197	0.14	0.051	0.35	<0.0001*	0.11	0.13	0.17	0.0147*	−0.028	0.70
DURSC3	197	0.23	0.0010*	0.23	0.001*	0.18	0.0133*	0.15	0.0413*	0.0023	0.97
VAL_PS	192	−0.24	0.0008*	0.13	0.071	−0.083	0.25	0.23	0.0014*	0.11	0.13
ORES	197	−0.28	<0.0001*	−0.042	0.56	−0.31	<0.0001*	0.11	0.12	0.28	<0.0001*
PRES	197	−0.38	<0.0001*	0.14	0.045*	−0.53	<0.0001*	0.27	0.0001*	0.52	<0.0001*

BASE_AMP = peak amplitude of pressure wave at the sensor at the base of tongue; BASE_DUR = duration of the pressure wave at the sensor at the base of tongue; PHAR_AMP = peak amplitude of pressure wave at the sensor in the hypopharynx; PHAR_DUR = duration of the pressure wave at the sensor in the hypopharynx; VELOCITY = speed at which the pressure wave propagates from base of tongue to hypopharyngeal sensor; OTT = oral transit time; RESPONSE = pharyngeal response time; DELAY = pharyngeal delay time; PTT = Pharyngeal Transit Time; DURMC2 = Duration of Tongue Base to Pharyngeal Wall Contact at the level of middle C2; DURIC2 = Duration of Tongue Base to Pharyngeal Wall Contact at the level of inferior C2; DURSC3 = Duration of Tongue Base to Pharyngeal Wall Contact at the level of superior C3; VAL_PS = vallecula to the pyriform sinus duration; ORES = approximate percent oral residue; PRES = approximate percent pharyngeal residue

* Statistical significance at $p < 0.05$

measures from VFS. The magnitude of significant Spearman correlation coefficients ranged from an absolute value of 0.14 to 0.53. All manometric measures had significant correlations with at least some of the continuous fluoroscopic measures.

Higher pressure wave amplitude at the base of tongue sensor was significantly associated with increased duration of tongue base to posterior pharyngeal wall contact at levels mid C2 and superior C3, and with decreased levels of pharyngeal delay time, bolus transit between the vallecula and pyriform sinus, and approximate percent oral and pharyngeal residue.

Increased duration of the pressure wave at the base of tongue sensor was significantly related to increases in timing measures from fluoroscopy (oral transit time, pharyngeal response time, pharyngeal transit time, and duration of tongue base to posterior pharyngeal wall contact at all three levels). It was also significantly correlated with increases in approximate percent pharyngeal residue.

Amplitude of the pressure wave at the hypopharyngeal manometric sensor was significantly positively correlated with duration of tongue base to posterior pharyngeal wall contact at the level of superior C3 and significantly negatively correlated with oral transit time, pharyngeal transit time, pharyngeal response time, and approximate percent of oral and pharyngeal residue.

The duration of the pressure wave at the hypopharyngeal sensor was positively correlated with a number of fluoroscopic measures. Increased duration of the pressure at the hypopharyngeal sensor was significantly associated with increased oral transit time, duration of tongue base to posterior pharyngeal wall contact at all three levels, increased bolus transit time between the vallecula and pyriform sinus, and increased pharyngeal bolus residue.

The velocity of the pressure wave propagation from the tongue base sensor to the hypopharyngeal sensor was significantly negatively correlated with pharyngeal response time and significantly positively correlated with approximate percent oral and pharyngeal residue.

Table 3 presents the Spearman correlation coefficients and significance levels for the manometric measures and the dichotomous measures from VFS. The amplitude of the pressure wave at the tongue base sensor was significantly higher when there was contact of the tongue base to posterior pharyngeal wall at all levels of closure and when there was no residue in the vallecula or pyriform sinus.

The duration of the pressure wave at the tongue base sensor was significantly longer when there was no contact of the tongue base to the posterior pharyngeal wall at either level C2 or C3 and when there was residue in the vallecula.

The amplitude of the pressure wave at the hypopharyngeal sensor was significantly greater when there was tongue base to posterior pharyngeal wall contact at all three levels and there was no residue in the vallecula or pyriform sinus.

Duration of the pressure wave at the hypopharyngeal sensor was significantly longer when there was no contact of the tongue base to the posterior pharyngeal wall at the level superior C3 or at both C2 and C3 and when there was residue in the vallecula and pyriform sinus.

Significantly faster velocity of the pressure wave propagation was correlated with no contact of the tongue base to the posterior pharyngeal wall at the level of mid C2, inferior C2, superior C3, or at both C2 and C3, as well as with presence of residue in the vallecula and pyriform sinuses.

Table 3 Spearman correlation coefficients and level of significance for manometric and dichotomous videofluoroscopic observations

Variable	*N*	BASE_AMP		BASE_DUR		PHAR_AMP		PHAR_DUR		VELOCITY	
		Spearman *r*	*p* value	Spearman *r*	*p* value	Spearman *r*	*p* value	Spearman *r*	*p* value	Spearman *r*	*p* value
MID_C2	197	0.16	0.02*	0.01	0.92	0.20	0.004*	−0.08	0.24	−0.15	0.035*
INF_C2	197	0.23	0.001*	0.00	0.98	0.25	0.0004*	−0.12	0.08	−0.26	0.0003*
SUP_C3	197	0.30	<0.0001*	−0.13	0.059	0.33	<0.0001*	−0.19	0.0062*	−0.22	0.0016*
C2C3	197	0.31	<0.0001*	−0.15	0.033*	0.33	<0.0001*	−0.22	0.0022*	−0.24	0.0007*
p−val	197	−0.36	<0.0001*	0.19	0.0091*	−0.50	<0.0001*	0.25	0.0004*	0.48	<0.0001*
p_pys	197	−0.18	0.0115*	0.01	0.93	−0.48	<0.0001*	0.16	0.0235*	0.35	<0.0001*

BASE_AMP = peak amplitude of pressure wave at the sensor at the base of tongue; BASE_DUR = duration of the pressure wave at the sensor at the base of tongue; PHAR_AMP = peak amplitude of pressure wave at the sensor in the hypopharynx; PHAR_DUR = duration of the pressure wave at the sensor in the hypopharynx; VELOCITY = speed at which the pressure wave propagates from base of tongue to hypopharyngeal sensor; MID_C2 = contact between tongue base and posterior pharyngeal wall at the level of mid C2; INF_C2 = contact between tongue base and posterior pharyngeal wall at the level of inferior C2; SUP_C3 = contact between tongue base and posterior pharyngeal wall at the level of superior C3; C2C3 = contact between tongue base and posterior pharyngeal wall at the level of both inferior C2 and superior C3; p-val = presence of bolus residue in the vallecula; p-pys = presence of bolus residue in the pyriform sinus

* Statistical significance at $p < 0.05$

Multivariate Analysis Results

All VFS measures or observations with significant ($p < 0.05$) Spearman correlations were entered into a multivariate analysis with each of the manometric measures. Table 4 summarizes the multivariate results.

Amplitude of the pressure signal at the tongue base sensor was correlated with increased duration of tongue base to posterior pharyngeal wall contact at the level of C3, decreased bolus transit time between the vallecula and pyriform sinus, and decreased percent pharyngeal residue. The multiple correlation coefficient for amplitude of the pressure signal at the tongue base sensor was 0.488, indicating that the combination of these VFS measures and observations explained 23.8% of the variation in amplitude of the pressure signal at the tongue base sensor.

Longer duration of the pressure wave at the tongue base sensor was related to increased duration of oral transit time, response time, and tongue base to posterior pharyngeal wall contact at the level of inferior C2, and lack of contact of tongue base to posterior pharyngeal wall at both levels C2 and C3. The multiple correlation coefficient was 0.517, indicating that these VFS measures accounted for 26.7% of the variation in duration of the pressure wave at the tongue base sensor.

At the hypopharyngeal sensor, the amplitude of the pressure wave was correlated with increased duration of tongue base to posterior pharyngeal wall contact at the level of mid C2, decreased pharyngeal response time, reduced percent pharyngeal residue, and no residue in the pyriform sinus. The multiple correlation coefficient was 0.597, indicating that 35.7% of the variance in amplitude of the pressure wave at the hypopharyngeal sensor was explained by these VFS variables.

Velocity of the pressure wave propagation between the tongue base and hypopharyngeal manometric sensors was negatively correlated with pharyngeal response time and positively correlated with approximate percent pharyngeal residue. The multiple correlation coefficient for velocity was 0.542, indicating that 29.4% of the variance in this

Table 4 Spearman partial correlation coefficients and level of significance for multivariate regression analysis of manometric and fluoroscopic measures or observations

Variable	*N*	BASE_AMP		BASE_DUR		PHAR_AMP		PHAR_DUR		VELOCITY	
		Partial *r*	*p* value	Partial *r*	*p* value	Partial *r*	*p* value	Partial *r*	*p* value	Partial *r*	*p* value
OTT	194			0.18	0.0017			0.26	<0.0001		
RESP	196			0.28	<0.0001	−0.21	0.0071			−0.23	0.0017
DELAY	194										
PTT	194										
DURMC2	197					0.23	0.0033	0.14	0.042		
DURIC2	197			0.41	<0.0001						
DURSC3	197	0.29	0.0001								
VAL_PS	192	−0.23	0.0013					0.18	0.012		
ORES	197										
PRES	197	−0.36	<0.0001			−0.42	<0.0001			0.52	<0.0001
MID_C2	197										
INF_C2	197										
SUP_C3	197										
C2C3	197			−0.17	0.021						
p-val	197							0.22	0.0004		
p_pys	197					−0.15	0.038				

BASE_AMP = peak amplitude of pressure wave at the sensor at the base of tongue; BASE_DUR = duration of the pressure wave at the sensor at the base of tongue; PHAR_AMP = peak amplitude of pressure wave at the sensor in the hypopharynx; PHAR_DUR = duration of the pressure wave at the sensor in the hypopharynx; VELOCITY = speed at which the pressure wave propagates from base of tongue to hypopharyngeal sensor; OTT = oral transit time; RESPONSE = pharyngeal response time; DELAY = pharyngeal delay time; PTT = Pharyngeal Transit Time; DURMC2 = Duration of Tongue Base to Pharyngeal Wall Contact at the level of middle C2; DURIC2 = Duration of Tongue Base to Pharyngeal Wall Contact at the level of inferior C2; DURSC3 = Duration of Tongue Base to Pharyngeal Wall Contact at the level of superior C3; VAL_PS = vallecula to the pyriform sinus duration; ORES = approximate percent oral residue; PRES = approximate percent pharyngeal residue; MID_C2 = contact between tongue base and posterior pharyngeal wall at the level of mid C2; INF_C2 = contact between tongue base and posterior pharyngeal wall at the level of inferior C2; SUP_C3 = contact between tongue base and posterior pharyngeal wall at the level of superior C3; C2C3 = contact between tongue base and posterior pharyngeal wall at the level of both inferior C2 and superior C3; *p*-val = presence of bolus residue in the vallecula; p-pys = presence of bolus residue in the pyriform sinus

Only significant partial correlation coefficients are given manometric measure is explained by pharyngeal transit time and percent pharyngeal residue.

Discussion

Univariate and multivariate analyses revealed significant relationships between manometric and fluoroscopic variables. In general, increases in pressure wave amplitude were correlated with increased duration of tongue base to pharyngeal wall contact and with reduced bolus transit times and residues. This pattern suggests that increased tongue base activity resulted in increased pressure on the bolus, resulting in a more efficient swallow characterized by shorter transit times and better bolus clearance.

Longer duration of the pressure waves was related to longer bolus transit times and higher pharyngeal residue. These correlations indicate that longer durations of the pressure waves are associated with worse swallow function, suggesting that a longer duration of pressure is needed to initiate and maintain bolus transit in the context of reduced pharyngeal pressure.

Approximate percent pharyngeal residue appears to be the most important VFS variable in reflecting pharyngeal pressure as measured from manometry. The measure correlated the highest with manometric measures in both the univariate analysis and the multivariate analysis. Increased pharyngeal residue is indicative of reduced pressure amplitude and increased duration of the pressure wave. In their study of concurrent manometry and fluoroscopy in 43 nondysphagic individuals, Dejaeger et al. [15] also found that vallecular residue was related to reduced tongue driving pressure. They found that residue restricted to the pyriform sinuses was related to reduced pharyngeal shortening, i.e., reduced laryngeal elevation, which is a measure observed on VFS rather than measured from manometry.

In their study of 20 patients with various medical diagnoses, Leonard et al. [13] found a high inverse correlation of -0.70 between peak pharyngeal pressure as measured by manometry and the pharyngeal constriction ratio (PCR), a measure of pharyngeal area. Although their study did not use simultaneous manometry and VFS and the material swallowed differed in both bolus size and consistency, the PCR appears to be an objective surrogate of pharyngeal strength. Nevertheless, despite their contention that the PCR can be calculated easily during routine fluoroscopy, the swallow clinician would need access to either digital fluoroscopy or an image digitizer as well as the measurement software in or near the fluoroscopy suite in order to make judgments on pharyngeal pressure disorders during the videofluoroscopic swallow examination. In our study, we chose to investigate several dichotomous observations from videofluoroscopy in the hope of finding a fast and easy way for clinicians to infer pressure difficulties from VFS during the swallow evaluation. Each of the dichotomous observations was significantly related to the amplitude of the pressure wave at the tongue base and hypopharyngeal sensors, as well as to the velocity of the pressure wave propagation. The swallow clinician can expect reduced pharyngeal pressures on swallows where there is residue in the vallecula or pyriform sinus or when there is no contact between the tongue base and posterior pharyngeal wall at any of the three levels examined in the study. These observations can be made in real time during the VFS examination by an experienced clinician.

This study adds to the growing body of literature indicating that pharyngeal pressures may be inferred from observations and measures taken from VFS. More research is needed, however, to examine the relationship between VFS parameters and UES functioning as measured with manometry, and how pharyngeal pressures and VFS measures correlate in patients with radiation-induced strictures. Future research should include these areas of investigation if swallow clinicians hope to use VFS to fully understand pressure disorders during the swallow.

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