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ORIGINAL ARTICLE

Correlating Dysphagia Severity with Fluoroscopic Parameters in Patients with Zenker's Diverticulum

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Abstract

Zenker's diverticulum (ZD) is an uncommon condition characterized by formation of a pseudodiverticulum in the hypopharynx that presents with considerable variability in swallowing symptomatology. Identifying radiographic features of ZD most associated with clinical impact could prove useful in counseling patients and predicting treatment response. This study was a retrospective case series of patients undergoing videofluoroscopic swallowing studies (VFSS) for Zenker's diverticulum at a tertiary dysphagia center. Anatomic parameters identified on VFSS of patients with ZD were correlated with subjective perception of swallowing using Eating Assessment Tool (EAT-10) scores. Upper esophageal sphincter (UES) opening at the point of maximal distention, area of diverticulum on the lateral view, height of the diverticulum, and entrance angle of the esophagus were measured. We identified 40 patients with ZD (52.5% male, mean age = 71.2 years). Narrow UES opening was significantly correlated with dysphagia severity ($r = -0.3445$, $p = 0.035$). Largest area of diverticulum ($r = 0.0188$, $p = 0.87$), diverticulum height ($r = 0.1435$, $p = 0.45$), and esophageal entrance angle ($r = 0.1677$, $p = 0.42$) were not correlated with EAT-10 scores. Maximum UES opening size was predictive of severity of swallowing dysfunction in patients with ZD. Size of ZD and the angle of bolus entry in patients with ZD are not predictive of swallowing dysfunction. Understanding the predictors of swallowing dysfunction will assist in counseling patients on postoperative expectations.

Keywords Zenker's diverticulum · Dysphagia · Videofluoroscopic swallowing study · Patient-reported outcome measure

Abbreviations

AHS	Alberta Health Services
SD	Standard deviation
EAT-10	Eating Assessment Tool-10
PSHR	Post-swallow hypopharyngeal reflux
UES	Upper esophageal sphincter
VFSS	Videofluroscopic swallow study
ZD	Zenker's diverticulum

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Introduction

Zenker's diverticulum (ZD) is one of the most common symptomatic esophageal diverticula, with an estimated annual incidence of two per 100 000 [1]. It is more prevalent in men than in women and typically presents in the seventh and eighth decades of life. [2–4] ZD is classically defined as a pulsion pseudodiverticulum formed through an area of weakness called the Killian dehiscence or Killian triangle between the cricopharyngeus muscle and inferior constrictor muscle. This is a low-resistance area which may herniate due to an increased hypopharyngeal pressure gradient related to uncoordinated relaxation of the upper esophageal sphincter upon swallowing. [5, 6] The principal symptom of ZD is progressive dysphagia, which may be present in excess of 90% of patients. Other associated symptoms include regurgitation of food, unprovoked aspiration, hypopharyngeal mucus collection, halitosis, coughing, hoarseness, globus pharyngeus, weight loss, and recurrent respiratory infections [7].

Diagnosis of ZD is formally made by endoscopy or videofluoroscopy that latter of which can also define the size of the diverticulum and its position [8]. Previously, upper esophageal sphincter (UES) opening was shown to be significantly reduced in ZD patients compared with controls, implicating UES opening as a primary mechanism for dysphagia in patients with a ZD [9]. Attempts to classify ZD by radiographic appearance, size, and stage of deglutition have been made previously; however, little has been written about degree of dysphagia and radiographic findings relating to the impact of ZD on swallowing, though anecdotally many practitioners intuitively connect diverticulum size to severity [5, 10]. Treatment outcome and quality of life monitoring for dysphagia patients can be accomplished using patient-centered subjective assessments of swallowing dysfunction severity. The Eating Assessment Tool (EAT-10) is a self-administered, symptom-specific outcome survey for dysphagia which has displayed excellent internal consistency, test–retest reproducibility, and criterion-based validity; it is a general dysphagia instrument, but initial validation studies demonstrated reduced swallowing dysfunction specifically among patients treated for ZD [11]. We sought to evaluate the relevance of several radiologic features of ZD and correlate them to the severity of swallowing impairment perceived by patients, with the objective of identifying features that would assist in patient counseling and outcome expectations.

Materials and Methods

Patient Selection and Data Collection

This study was approved the University of Calgary Conjoint Health Research Ethics Board (protocol #20-0262). A retrospective cohort was developed by identifying patients with ZD who underwent a VFSS at the Alberta Health Services (AHS) Outpatient Dysphagia Clinic between January 1, 2016, and December 31, 2019, in the Calgary Health Region. Health records were reviewed for basic demographics. Swallowing symptom severity was measured according the Eating Assessment Tool (EAT-10) at the time of VFSS or first clinic appointment.

VFSS examinations were performed according to regional AHS standard protocols with patients challenged with thin, honey, nectar-thick, pureed, solid, and mixed consistency barium swallows, as deemed appropriate by the administering speech language pathologist. VFSS studies were evaluated according to the MBSImp protocol [12]. Subjects received barium paste in sandwich and cookie textures (Esobar 60% w/w), barium powder in thick fluid textures (E-Z-HD 98% w/w), and liquid barium with thin fluids textures (Polibar Plus 105% w/v, Bracco E-Z-EM Canada, Inc.; Anjou, QC). The fluoroscopic studies were recorded digitally with Siemens Artis Zee (Siemens Healthcare GmbH, Erlangen, Germany) or Siemens Axiom Luminos dRF (Siemens Healthcare GmbH, Erlangen, Germany) with a 24.1-mm ring used as a reference standard taped in the midline of the submental region.

Radiologic anatomic parameters were measured by electronic review of lateral images recorded on Impax 6 (Agfa, Waterloo, ON) records. Both authors reviewed the measurements for accuracy. Measurement of the maximal UES opening (Fig. 1a) and diverticulum area (Fig. 1b) in lateral view used the markup caliper and markup area functions, respectively. In order to standardize how the diverticulum is measured, we defined the upper border of the diverticulum by drawing a plane connecting the tip of cricopharyngeus muscle to the inflection point formed at the posterior esophageal wall where the diverticulum first projects. Esophageal inlet angle, a novel measure, was calculated using the markup angle function and defined as the angle a bolus follows to enter the esophagus in reference to the natural angle of the pharynx (Fig. 1c). The first vector consisted of a plane along the posterior pharyngeal and esophageal walls. The second vector consisted of a line intersecting two inflection points: the first demarcating the departure of normal linear pharynx to abnormal pharyngeal contour (Fig. 1c, point x) followed by the return to normal esophageal orientation (Fig. 1c, point y). Conceptually, this can be understood as how parallel versus perpendicular the esophageal inlet angle is relative to the natural plane of the pharyngoesophageal segment: inlet angle of zero degrees is straight while 90 degrees is perpendicular. The diverticulum height (Fig. 1d) was measured using the markup caliper function. All measurements were taken from frames with maximal distension during swallowing with a large bolus.

Statistical Evaluation

Categorical data were summarized by tables and frequencies. Descriptive statistics were reported as mean with standard deviation (SD) for continuous variables or frequencies and percentages for nominal variables. Subjective perception of swallowing using EAT-10 scores was correlated to upper esophageal sphincter (UES) opening at the point of maximal distention, area of diverticulum on the lateral view, length of the diverticulum, and the entrance angle of esophagus using the Pearson correlation coefficient. All p-values were two-sided and the level of significance set at < 0.05. Statistical analysis was performed with STATA MP/version 13.0 (StataCorp, College Park, TX).

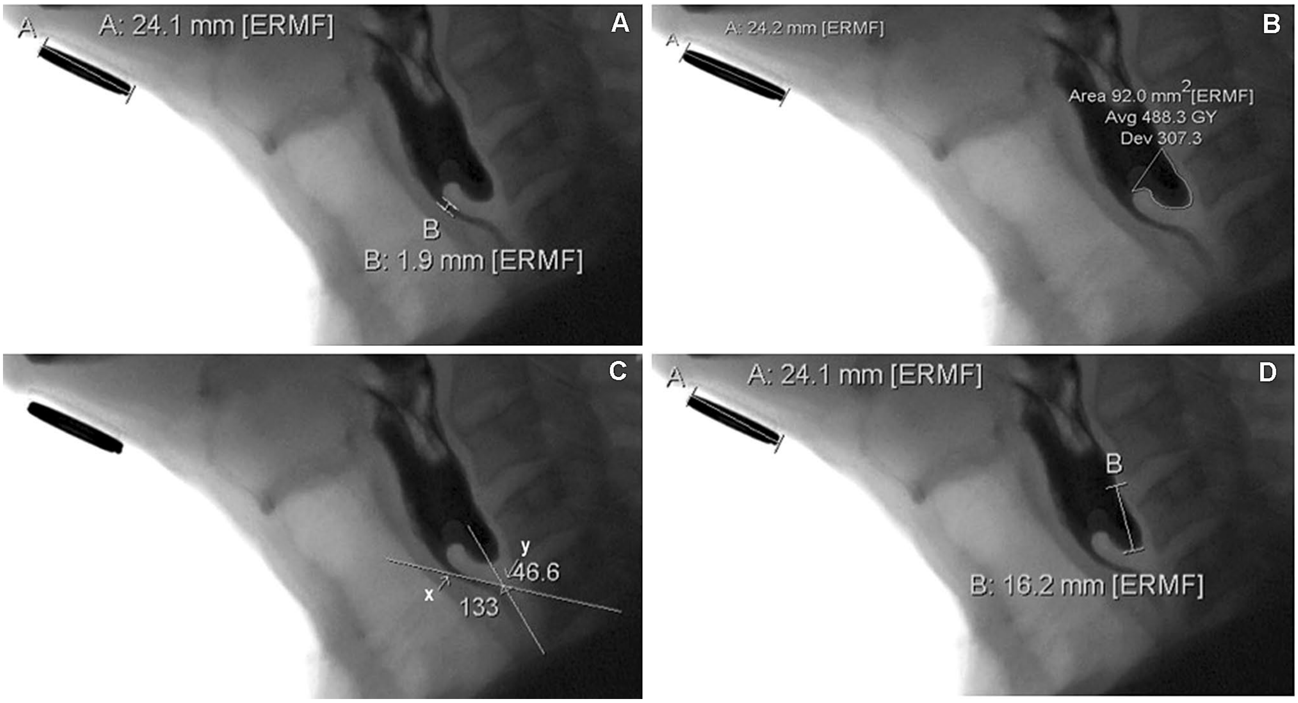

Fig. 1 Videofluoroscopic swallow study images during maximal distension on the lateral view. **a** UES opening in mm **b** diverticulum area in mm^2 **c** Esophageal inlet angle **d** diverticulum height in mm. UES = upper esophageal sphincter

Results

Patient Demographics and Zenker's Diverticulum Features

A total of 43 consecutive preoperative ZD patients were identified in our dataset between January 1, 2017, and December 31, 2019, with full outpatient VFSS available in 40. Of the patients reviewed, 21 patients were male (52.5%) and 19 were female (47.5%). The mean age of patients in our study population was 71.2 years (SD = 11.84). Table 1 demonstrates mean measures for the anatomic features of the diverticulum for our study population, stratified by sex. Diverticulum features were similar between men and women but slightly larger in men. Evaluation of general pharyngeal function through the MBSImp outcomes on pharyngeal and esophageal function revealed generally mild pharyngeal dysphagia (median total score = 5, range 0–15) and esophageal dysfunction (median = 2, range = 0–3). Penetration, considered as penetration–aspiration scale scores greater than two, occurred in 17.5% (7/40) patients, while aspiration occurred in 10% of patients. Penetration on refluxate from the diverticulum was common, but the majority of patients demonstrating aspiration were found to aspirate on the initial swallow rather than on refluxate.

Anatomic Correlates to Subjective Dysphagia Severity

Figure 2 demonstrates the anatomic features evaluated and their correlations with subjective dysphagia symptoms. Narrow UES opening on maximal distension on the lateral view of subjects was significantly correlated with higher EAT-10 scores ($r = -0.3445$, $p = 0.035$, Fig. 2a). Diverticulum area

Table 1 Radiologic parameters of interest

Parameter	All patients	Male	Female
UES opening (mm ± SD, n)	4.00 ± 1.93, 36	4.28 ± 2.16, 20	3.65 ± 1.62, 16
Diverticulum area (mm^2 ± SD, n)	242.2 ± 187.6, 36	286.4 ± 214.2, 20	186.9 ± 134.5, 16
Esophageal inlet angle (degrees ± SD, n)	40.10 ± 12.37, 29	40.29 ± 12.90, 14	39.93 ± 12.31, 15
Diverticulum height (mm ± SD, n)	24.46 ± 13.37, 36	27.50 ± 14.16, 20	20.66 ± 11.63, 16

UES upper esophageal sphincter

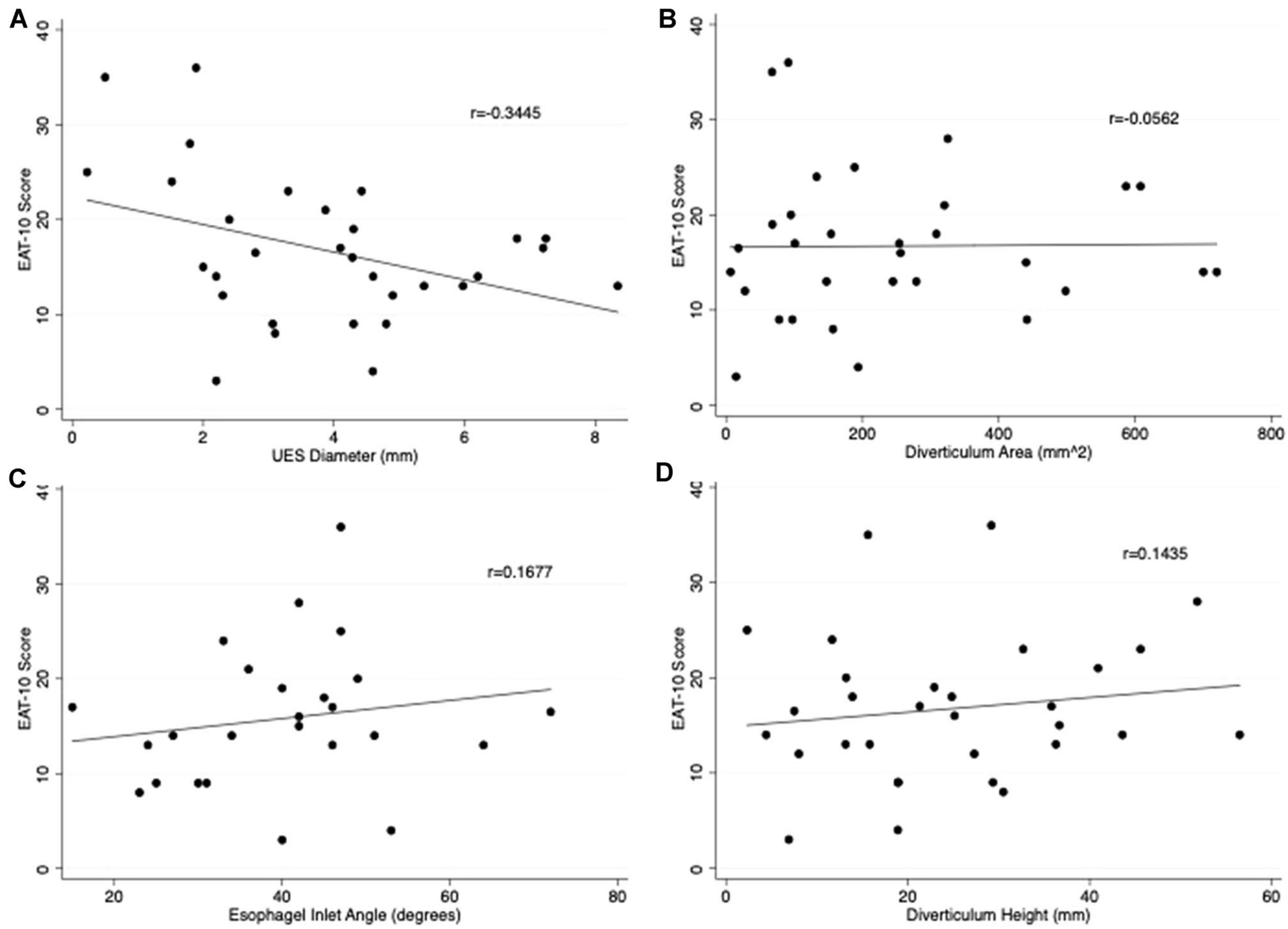

Fig. 2 Dependence of subjective swallowing dysfunction on anatomic parameters identified on videofluoroscopic swallowing study in patients with Zenker's diverticulum. **a** UES opening in mm **b** diverticulum area in mm^2 **c** Esophageal inlet angle **d** diverticulum height in mm. UES = upper esophageal sphincter

showed no significant correlation with swallowing scores (r = – 0.0329, *p* = 0.8716, Fig. 2b). The relationship between EAT-10 scores and the angle of bolus entry determined between the posterior esophageal wall and points of inflection of esophageal wall contour was analyzed and no correlation was identified (r = 0.1667, *p* = 0.42, Fig. 2c). Maximal diverticulum height was not correlated with swallowing dysfunction relationship (r = 0.1435, *p* = 0.45, Fig. 2d).

Discussion

Dysphagia is the most prominent symptom of ZD, but limited data exist demonstrating the association of ZD anatomic characteristics with the degree of dysphagia symptoms on patient presentation. This study evaluates a cohort of 40 ZD patients who underwent VFSS investigation to test the correlation of several fluoroscopic parameters with dysphagia severity.

This cohort demonstrated that UES opening was the primary anatomic factor which predicted dysphagia severity, while distortion of the natural pharyngoesophageal segment is less impactful. From a clinical perspective, it is natural to identify a large diverticulum and assume this will be problematic. However, our data indicate that size of the diverticulum's maximal height and area on the lateral view were not correlated to the degree of dysphagia, with several diverticuli noted to be quite large. Intuitively, this is logical as patients with large diverticuli have ostensibly been affected for longer duration in order to allow progressive enlargement; while these patients may be more affected by other symptoms such as regurgitation, their swallowing limitation may be less dramatic. A case series by Bergeron et al. (2012) compared dysphagia symptoms across groups based on diverticulum size and found that preoperative assessment of dysphagia characteristics in ZD patients revealed post-swallow hypopharyngeal reflux (PSHR) was predictive of a ZD larger than 1 cm [13]. However, the authors did not correlate the degree of dysphagia symptoms to diverticulum size. In a large series of patients evaluated for surgical treatment efficacy, diverticulum height and size correlated with regurgitation and overall dysphagia score correlated with pouch depth [14]. One notable difference between that report and our study is that the esophageal opening was thought to be an inconsistent measure and not included their data analysis. By defining our UES opening measure as the largest opening at any location in the UES rather than specifically at the tip of the cricopharyngeus, this avoids some of the inconsistency with measurement. In addition, our study includes all patients identified with ZD, rather than focusing on patients who elect for surgical treatment.

From a functional perspective, it would seem that if the UES angle is displaced and forces bolus direction away from the natural vertical plane, this may cause patients worsened swallowing symptoms. However, we found the angle of esophageal inlet opening was independent of dysphagia severity. It is noteworthy that the patients with vertical esophageal orientation tended to have low EAT-10 scores, but there was considerably heterogeneity among the patients with more horizontally displaced orientation. Symptom variability was a general characteristic for our dataset, with high heterogeneity among symptom scores likely affecting the statistical outcomes. This is a familiar problem for treating physicians, as some ZD patients elect nonoperative management given they feel minimal clinical impact from their diverticulum.

In a study by Allen et al. (2017), 40 patients underwent preoperative and post-cricopharyngeal myotomy videofluoroscopic swallow studies (VFSS) with EAT-10 scores prospectively recorded [15]. Despite the presence of pouch remnants and retained barium on VFSS, there was no correlation with reported symptom severity. Combined with our findings, postoperative dysphagia severity appears independent of remnant diverticulum pouch and instead may reflect a function of esophageal sphincter opening. Our findings are also congruent with a prospective study by Yip et al. (2006), which found that UES opening in patients with cricopharyngeal dysfunction was 57% of that in normal controls and that surgical repair returned UES opening to normal range [16]. Symptom assessment in their study was limited to the presence of hallmark ZD symptoms preoperatively and a binary subjective assessment of whether they felt less affected after surgery, rather than a validated swallowing symptom instrument. The pathogenesis of cricopharyngeal dysfunction is commonly attributed to incoordination of the swallowing mechanism; however, our data build further support that the anatomic distortion resulting from the formation of a ZD is less of a factor in the subsequent dysphagia than the esophageal inlet narrowing. Thus, UES opening dimension should be considered the strongest contributor to dysphagia severity.

Our series found a sizeable portion of patients had significant oropharyngeal dysfunction on VFSS scoring, which is to be expected given the pathology and average advanced age in this population. However, an underappreciated aspect of dysphagia symptoms among patients with ZD is the contribution from esophageal dysfunction. Many ZD patients are treated surgically and report excellent dysphagia symptom resolution, sometimes with variable degree of success depending on technique and outcome measure [14, 17–20]. Nonetheless, this may reflect a bias among patients since they minimize additional symptoms based on decreased difficulty or distress with swallowing. It stands to reason that more distal esophageal dysfunction will not improve following treatment of the diverticulum, and so, these coexistent conditions will likely persist. Studies assessing esophageal dysmotility by fluoroscopy in ZD and hiatus hernia patients report dysmotility in all ZD patients but only 30% with hiatus hernia and reflux [21]. Manometric studies of esophageal function have been varied, with reports of varied pharyngeal and esophageal pressure abnormalities [22, 23]. Increased esophageal dysmotility for solid textures is seen with advanced age, so given our study population's mean age of 71 years, this is a possible confounder [24]. Further investigation into esophageal dysfunction and contribution to symptoms as well as diverticulum development will be useful for understanding disease pathophysiology.

There are several limitations to this study that should be noted. Obtaining measures of a three-dimensional structure from two-dimensional images has inherent error. Although the esophageal inlet with a ZD often looks like a narrow slit on lateral views, it cannot be assumed that this dimension is of equivalent size in the anteroposterior (AP) view. Studies using fresh animal and human cadavers describe a kidney bean shape to the UES [25, 26]. In some of our patients, accurately measuring shapes was additionally challenged by the barium shadow effect, which obscures details of some shapes. Specifically, attempts to accurately measure the dimension of esophageal opening in AP views for ZD patients was unreliable due to the barium shadow persisting in the pouch, which precludes clear view of the opening. Ultrasound can provide a better assessment of esophageal opening, but this has not been tested in ZD, so it is difficult to predict whether air or mixed density within the diverticulum would preclude this technique. Furthermore, additional clinical and lifestyle factors including comorbidities, medications, preexisting dysmotility, and compensatory dietary changes may contribute to perceived dysphagia severity in our series. Finally, this cohort comprised a single population at one tertiary academic facility, and the data may not be widely generalizable to other populations. A multicenter prospective trial with a larger cohort would allow for subgroup analysis and increased confidence and improve ability to further understand these predictors of ZD-related dysphagia severity.

Conclusion

We identified a cohort of 40 ZD patients with prospectively collected VFSS and EAT-10 measures. Overall, our findings suggest that narrow UES opening was the only radiographic parameter associated with subjective perception of dysphagia severity. Size of ZD and the angle of bolus entry in patients with ZD are not predictive of swallowing dysfunction. Thus, understanding the anatomic predictors of swallowing dysfunction will assist in counseling patients on postoperative expectations.

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Compliance with Ethical Standards

Conflict of interest The auhtors declare that they have no conflict of interest.

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