Esophageal Transit Times Vary with Underlying Comorbid Disease

Anna Miles, PhD¹, Kirany Bennett, MSc¹, and Jacqui Allen, MD, FRACS¹

Abstract

Objectives. Little is known about esophageal transit times (ETT) in relation to underlying comorbid disease or aspiration risk. Our study evaluated liquid ETT in patients relative to underlying comorbid disease and compared this with ETT in healthy adults. We examined whether prolonged ETT was associated with swallowing risk.

Study Design. Prospective observational study.

Setting. Radiology department.

Subjects. Patients included those referred to speech pathology for a videofluoroscopic study of swallowing (VFSS) within a tertiary hospital.

Methods. A total of 617 patients (49% female; mean ± SD age, 77 ± 15 years) and 139 healthy adults (56% female; age, 59 ± 22 years) were included. All patients underwent a standardized VFSS with esophageal screening. Patients were categorized by chief underlying disorder: previous stroke (n = 207), other neurologic condition (n = 188), respiratory conditions (n = 91), or gastroenterology conditions (n = 131). All VFSSs were analyzed with objective measures. ETT and penetration-aspiration scores were compared between groups.

Results. Advancing age was significantly associated with increased ETT (P < .05). When controlling for age, mean 20-mL ETT remained significantly different across groups: healthy adults, 11 seconds; stroke, 17 seconds; other neurologic condition, 15 seconds; respiratory conditions, 14 seconds; and gastroenterology conditions, 9 seconds (P < .001). One-third of patients aspirated; no healthy adults aspirated. Increasing ETT was associated with aspiration events (P < .001).

Conclusions. Liquid ETTs differ among patients with different underlying primary diagnoses. Patients following stroke show significantly prolonged ETT and increased risk of aspiration. Prolonged ETT may influence symptom complaint and warrants consideration.

Keywords
deglutition, dysphagia, videofluoroscopy, pharynx, esophagus, motility

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assessment approach to these patients so that we can offer appropriate explanation, referral, and management.

Our institution has been performing esophageal screening during VFSS since 2010 and has undertaken normative work on esophageal transit times (ETTs) in adults across the age range, examining a variety of textures—liquid, paste, and pill.\(^9\) Mean liquid ETT in 118 healthy adults (age, 20-98 years) was 10.7 seconds (interquartile range, 4.33 seconds) and increased in duration with aging.\(^9\) Currently, there are no data available on how comorbidities and concomitant disease might influence ETTs on screening VFSS, nor has ETT been examined in relation to risk of airway violation. It is recognized that diabetes mellitus and autoimmune conditions, such as scleroderma, increase the risk of esophageal dysmotility, but the effect of more prevalent underlying disorders, such as cerebrovascular accident and chronic obstructive pulmonary disease, have not been described.

This study explored whether any “class” effects were identifiable when ETT was compared among patients with different underlying comorbid diseases and whether ETT differed in patients with comorbid disease when compared with normal adults. We also sought to correlate ETT with airway threat events through use of the Penetration-Aspiration Scale (PAS).\(^11\)

Research questions were as follows:

1. Are ETTs different between healthy adults and patients referred for VFSS?
2. Do ETTs increase with age in healthy adults and patient groups?
3. Do ETTs differ among different patient groups (ie, those with different primary pathologies)?
4. Is penetration-aspiration associated with ETT?

**Methods**

This study received appropriate regional ethics approval (New Zealand Health and Disability Ethics Committee 13/STH202 and University of Auckland Human Patients Ethics Committee 9263).

**Participants**

A total of 139 healthy adults (60 men, 79 women) were recruited through local advertisement.\(^9\) Participant age reflected the adult life span (mean ± SD age, 59 ± 21.50 years; range, 20-99 years). Exclusion criteria included previous swallowing difficulties or any health condition known to disrupt swallowing function.\(^9\) Healthy volunteers completed the Eating Assessment Tool–10,\(^12\) the Sydney Swallowing Questionnaire,\(^13\) the Functional Oral Intake Scale,\(^14\) and the Mini-Nutritional Assessment prior to enrollment.\(^15\) Participants were excluded if their scores were not in the reported normal ranges.

A total of 617 patients with dysphagia (primary referral diagnosis: stroke, \(n = 207\); other neurologic, \(n = 188\); respiratory, \(n = 91\); gastroenterology, \(n = 131\)) were referred to 1 hospital for VFSS (2015-2018). Patients in the “other neurologic” group were primarily people with a diagnosis of Parkinson’s disease (80%). The remaining 20% included myotonic dystrophy, cerebral palsy, multiple sclerosis, traumatic brain injury, and vascular dementia. Patients in the respiratory group included primary diagnoses of chronic obstructive pulmonary disease, lung cancer, and lower respiratory tract infections.

**Videofluoroscopic Study of Swallowing**

A standard protocol was followed for healthy adults and patient groups.\(^9,16\) Studies were performed in a radiology suite with a videofluoroscope (Toshiba; Tokyo, Japan), recorded at 30 frames per second, and exported in MP4 format onto a USB drive. Timing information was superimposed on the fluoroscopic recording in 100ths of a second with a Horita VS-50 Video Stopwatch (Horita; Capistrano Beach, California). A medical radiation technician and a speech pathologist were present at all procedures.

For the esophageal screen, the patient was screened in the anterior-posterior plane and presented with a 20-mL fluid bolus (E-Z Paque 96% w/v diluted to 19%). The patient was positioned standing, where able, and asked to “swallow all in one go” to avoid deglutitive inhibition. If a patient swallowed more than once, a second 20-mL bolus was given, and the patient was asked to “try hard not to take a second swallow.” The medical radiation technician followed the bolus from the oral cavity through to the lower esophageal sphincter until clearance into the stomach. Screening was continued for up to 20 seconds. If there was remaining residue in the esophagus, screening halted for 20 seconds, then recommenced for another 20 seconds. If residue was still present, the patient was asked to take a dry swallow to determine if clearance occurred. At 60 seconds, screening was terminated irrespective of presence of residue to limit radiation exposure in keeping with local policy.\(^4,9\)

**Excluded Data**

Overall, 230 patients were excluded from analysis (stroke, \(n = 115\); other neurologic, \(n = 64\); respiratory, \(n = 37\); gastroenterology, \(n = 14\)) due to difficulty positioning, high-risk aspirator, or previously completed screen.\(^4\) Multiple-swallow trials were not included. This range of exclusions is in keeping with previous work.\(^4\)

**Measures**

VFSS were analyzed frame by frame with QuickTime Media Player (Apple, Cupertino, California). ETT was measured from head of bolus passing from the piriform sinus through the upper esophageal sphincter to tail of bolus clearing the lower esophageal sphincter.\(^4,9,16\) Each patient’s 20-mL esophageal screen was timed (seconds) or assigned a value of 60 seconds if the bolus did not clear. All VFSSs were measured by clinicians trained and experienced in VFSS analysis. Twenty percent of the measurements were double-rated by a second researcher, with substantial interrater reliability confirmed for all measures (intraclass correlations = 0.98, \(P < .001\)). Each full VFSS was assigned a
maximum penetration-aspiration score per the PAS and derived from images screened in the lateral plane.¹¹

**Data Analysis**

Data were inputted into Excel (Microsoft; Redmond, Washington) and explored with descriptive statistics, including mean, range, and standard deviations. Graphing was completed with Excel. Statistical analysis was performed with SPSS 20 (IBM, Chicago, Illinois). Correlations were explored among groups, age, PAS, and ETT. Spearman and Kendall tau correlations were used for nonparametric data. Comparisons of age, PAS, and ETT across groups were made with analysis of variance or the nonparametric Kruskal-Wallis test with post hoc testing. Due to a previously reported association between increasing age and increasing ETT,⁹ 1-way analysis of covariance was used to explore differences among pathologies while adjusting for this covariate. Interrater reliability between blinded raters was confirmed with intraclass correlation.

**Results**

A total of 617 patients (49% female; age, 77 ± 15 years) and 139 healthy adults (56% female; age, 59 ± 22 years) were included in analyses. Patients were grouped into stroke survivors (n = 207), other neurologic conditions (n = 188), respiratory conditions (n = 91), and gastroenterology conditions (n = 131).

Age differences were found among groups, with the gastroenterology group significantly younger than all other patient groups (F = 46.87, P < .05). Thirty-three percent of all patients aspirated (201 of 617), but no healthy adults aspirated (Table 1).

<table>
<thead>
<tr>
<th>Group</th>
<th>PAS Score, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy adults (n = 139)</td>
<td>139 (100)</td>
</tr>
<tr>
<td>Stroke (n = 207)</td>
<td>69 (33)</td>
</tr>
<tr>
<td>Other neurologic condition (n = 188)</td>
<td>94 (50)</td>
</tr>
<tr>
<td>Respiratory (n = 91)</td>
<td>42 (46)</td>
</tr>
<tr>
<td>Gastroenterology (n = 131)</td>
<td>99 (76)</td>
</tr>
</tbody>
</table>

Abbreviation: PAS, Penetration-Aspiration Scale.

**Influence of Age**

There was a positive correlation between age and ETT in healthy adults and patient groups (rₛ = .12, P < .001), with increasing age associated with longer ETT. Figures 1 and 2 show the ETT association with age in healthy adults and across comorbidity groups, respectively.

**Influence of Primary Pathology**

Mean 20-mL ETT was significantly different across patient groups when controlling for age: healthy normal (age adjusted), 11 seconds (95% CI, 8-13); stroke, 17 seconds (95% CI, 14-20); other neurologic conditions, 15 seconds (95% CI, 12-17); gastroenterology, 14 seconds (95% CI, 12-17); and respiratory, 9 seconds (95% CI 5-13), F(4, 512) = 3.796 (P < .001). Pairwise comparisons show significant differences in ETT between healthy and stroke (P < .05) and respiratory and stroke (P < .05; Figure 3).

PAS also varied with group assignment, with significantly greater aspiration rates in patients as compared with healthy adults (χ² = 163.49, P < .001; Table 1). Elevated PAS was correlated with prolonged ETT (rₛ = 0.16, P < .001) and older age (rₜ = .252, P < .001). Post hoc testing confirmed that healthy adults were significantly different to all patient groups (P < .001) and that patients in the stroke, neurologic, and respiratory groups had significantly higher PAS scores than those in the gastroenterology group (P < .001).

**Discussion**

Until recently, routine assessment of the esophagus has not been undertaken during VFSS, and the potential for missing esophageal pathology existed. With recognition that the esophagus plays a significant part in symptom generation in the pharyngolarynx, attention has turned to how this interplay is exhibited and what influences symptom generation. This is the first study to describe ETTs between healthy adults and patients with differing underlying comorbid diseases with use of a standardized VFSS protocol that includes esophageal screening. Referred patients demonstrated longer
duration of esophageal transit for liquid barium, which was greatest in the stroke survivors’ group. These differences persisted even when controlling for the effects of age, a known factor increasing esophageal transit duration.\textsuperscript{9,17} Furthermore, we identified greater penetration-aspiration scores in patient groups, and these were significantly correlated with extended ETT. It is not possible from the data in this study to determine whether the prolonged ETT was a driver of airway risk or simply represents a variable demonstrating global swallow impairment in affected individuals.

**Influence of Age**

Swallowing effectiveness is influenced by age-related changes to the swallowing mechanism.\textsuperscript{18,19} Typical age-related changes may result in oral, pharyngeal, and esophageal compensations, even in the healthy aging population. In the elderly esophagus, the high pressure zone associated with upper esophageal sphincter innervation is reduced in length and stimulability.\textsuperscript{18} Disorders of the esophagus, including esophageal diverticula, esophageal rings or webs, and achalasia, occur more frequently in middle-aged and older patients.\textsuperscript{20} Longer ETT, as
seen in this and previous work, is a normal consequence of aging.\textsuperscript{9,17,21} When performing VFSS esophageal screens, clinicians must consider age when interpreting ETTs, as well as the presence of comorbid disease.\textsuperscript{9} Older adults may be expected to have slower esophageal transit, which may influence which dietary strategies are recommended. Other factors that may coexist and affect swallowing in older adults include medication use, sarcopenia, and frailty. Consideration of the constellation of factors at play will be important in therapeutic management strategies.

**Influence of Underlying Pathology**

Age was controlled in this study to determine if ETT was influenced by underlying pathology independent of age. Patients with primary respiratory conditions had ETTs equal to those of healthy adults despite being the oldest patient cohort, and yet they demonstrated the second-highest rate of aspiration. This may indicate sensory dysfunction in the upper airway or incoordination of swallow-breathe cycles. Aspiration in a patient with respiratory compromise may result in serious consequences in an already-strained pulmonary system. Further work is needed to examine these relationships in detail.

Patients after stroke had significantly longer ETTs than healthy adults and patients with respiratory diagnoses. They also demonstrated the greatest rate of aspiration (42%). This is a significant finding. Standard practice internationally is to focus on oropharyngeal impairments after stroke, without consideration of the esophagus. Many typical treatments of oropharyngeal dysphagia have a negative impact on esophageal transit. Thickened fluids are the most common dysphagia management strategy,\textsuperscript{22,23} and their underlying premise is slowing transit. In the mouth and pharynx, this has the advantage of reducing aspiration risk. However, in the esophagus, this is likely to be far less useful.\textsuperscript{9,21} Manometric studies have shown esophageal effects from other commonly prescribed oropharyngeal compensatory strategies, with effortful swallow increasing esophageal peristalsis and with Mendelsohn maneuver decreasing esophageal peristalsis.\textsuperscript{24} We need to understand whether sensory and motor functions are affected in this condition, as is likely. All patients with neurologic disease should receive an esophageal screen alongside their VFSS assessment of oropharyngeal function. It is critical that esophageal motility competence is understood before engagement in compensatory and rehabilitation interventions to allow optimized holistic multidisciplinary clinical reasoning to occur.

**Limitations**

This retrospective observation of consecutive patients through a VFSS clinic is large, providing rich heterogenous data. However, there are missing data, with a portion of patients unable to complete an esophageal screen due to severity of swallowing disorder or to difficulties in positioning to view the lower esophageal sphincter.\textsuperscript{4} This may have excluded more patients with severe neurologic conditions necessitating a wheelchair. Stroke severity may therefore be underreported in this study. Implications for patients with >1 conclusive diagnosis are not explored in this study. Multiple diagnoses are common, particularly with increasing age, and concurrent pathologies were not explored. The effect of medicines on esophageal transit was also not addressed in this large cohort study but would be of interest in future research. The presence of diabetes was not routinely recorded and may also have influenced esophageal function when present. Finally, although we used penetration-aspiration scores as a marker of airway risk, we did not have data regarding the rate of aspiration pneumonia in the affected patient group.

**Conclusions**

ETTs differ between healthy adults and patients referred to a VFSS clinic with a range of underlying medical conditions. Prolonged ETTs were seen in stroke survivors, and this correlated with significantly increased presence of aspiration. Patients following stroke should routinely be screened for swallowing deficits across all phases. Speech pathologists should be mindful of concurrent esophageal impairments in patients complaining of oropharyngeal dysphagia and should consider the impact of treatment recommendations on the whole deglutitive system.

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**Author Contributions**

Anna Miles, overall research coordination, study design, data collection, analysis, write-up; Kirany Bennett, data collection, data analysis, write-up; Jacqui Allen, study design, analysis, write-up.

**Disclosures**

**Competing interests:** Anna Miles, employment: The University of Auckland; Kirany Bennett, student: The University of Auckland; Jacqui Allen, employment: The University of Auckland, employment: Auckland ENT Ltd.

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**References**


