



Cross-sectional Study

The level of impaired esophageal bolus transit measured by multichannel intraluminal impedance: Cross-sectional study

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ABSTRACT

Background: Esophageal motility disorders (EMDs) are often diagnosed manometrically, yet the underlying pathology is not always clear. Esophageal function testing (EFT), which incorporates manometry and multichannel intraluminal impedance (MII), is considered a useful tool in the assessment of EMDs.

Objective: This study aims to assess the most likely level of impaired bolus transit within the esophagus which may help further localize and characterize EMDs.

Methods: In a retrospective study design, we reviewed consecutive EFTs over a period of 12 months. Data included diagnosis, presenting symptoms, and EFT results of liquid and viscous swallows. Each patient underwent 10 liquid and 10 viscous swallows, and bolus transit is measured at 5, 10, 15 and 20 cm above the gastroesophageal junction (GEJ). We recorded the initial level of impaired bolus transit for each swallow.

Results: A total of 2358 swallows in 118 patients was included for analysis. Of these, 837 swallows (35.5%) were incompletely transmitted. The proportions of impaired bolus transit were 39%, 41%, 15.6%, 4.4% at 20 cm, 15 cm, 10 cm, and 5 cm above the GEJ, respectively. The common symptoms at presentation were dysphagia (47%), heartburn (44%), chest pain (24.6%) and regurgitation (18%). The mean lower esophageal sphincter (LES) pressure was 24 ± 13.9 mmHg whereas the mean contraction amplitude was 84 ± 46.6 mmHg.

Conclusion: In patients with abnormal esophageal clearance, the most likely levels of impaired bolus transit are 15 and 20 cm above the GEJ. These levels of the esophagus should be a focus of attention in future studies evaluating the pathophysiology of esophageal dysmotility.

1. Introduction

Esophageal manometry is a principal method to assess esophageal motor function and is commonly used in clinical practice to investigate upper gastrointestinal (GI) symptoms and pathologies [1,2]. However, manometry is limited as it only evaluates the contractility patterns of the esophagus without information about the current of intraluminal contents [3]. The addition of impedance measurement can provide more details. Multichannel intraluminal impedance (MII) measures changes in resistance of the electrical current during a bolus movement within the esophagus and can distinguish its contents: intraluminal air which exhibits high impedance versus liquid which exhibits low impedance [2,3]. The role of MII in determining the most likely level of impaired bolus

transit has sparsely been described in the literature. This necessitates more data gathering for the utility of this technique; hence we conducted this study.

Understanding the physiology of bolus transit is essential to recognize different esophageal disorders and to appropriately target management. Recent advancements in how to approach patients with esophageal motility disorders (EMDs) involved modifications in instrumentation and diagnostic modalities and the availability of different therapeutic options [4]. Despite this progress, it is still difficult to distinguish EMDs relying only on the symptoms of esophageal dysmotility such as chest pain, regurgitation, or dysphagia as these symptoms often overlap between esophageal disorders [4,5]. Because of such similarity in clinical presentation, it is imperative, not only to determine

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the underlying pathology but also, if feasible, to precisely localize the level of the affected area within the esophagus. Therefore, we conducted this study to determine the most likely level of impaired bolus transit within the esophagus in patients with clinical features of EMDs.

2. Methods

We conducted this retrospective longitudinal study in the Gastrointestinal (GI) Lab at the University Hospital Case Medical Center in Cleveland, Ohio, over a period of 12 months. This study was approved by the local ethics board and conducted according to the Declaration of Helsinki.

We reviewed the esophageal function test (EFT) results for all patients during the study period. The study included consecutive adult patients who presented with symptoms suggestive of esophageal dysmotility and were referred to undergo a diagnostic EFT. Patients with known esophageal cancer were excluded. Data were anonymized to include no patients' identification. We collected the raw data which included patients' sex, symptoms, diagnosis, percentage of peristalsis, distal contraction amplitude, lower esophageal pressure, depth of probe, and impedance measurements (numbers and levels of complete versus incomplete, and liquid versus viscous swallows) for each patient.

We reviewed the bolus transit records for both liquid and viscous swallows. Every patient underwent 10 swallows with each liquid and viscous bolus and all tests were done while patients were in a sitting

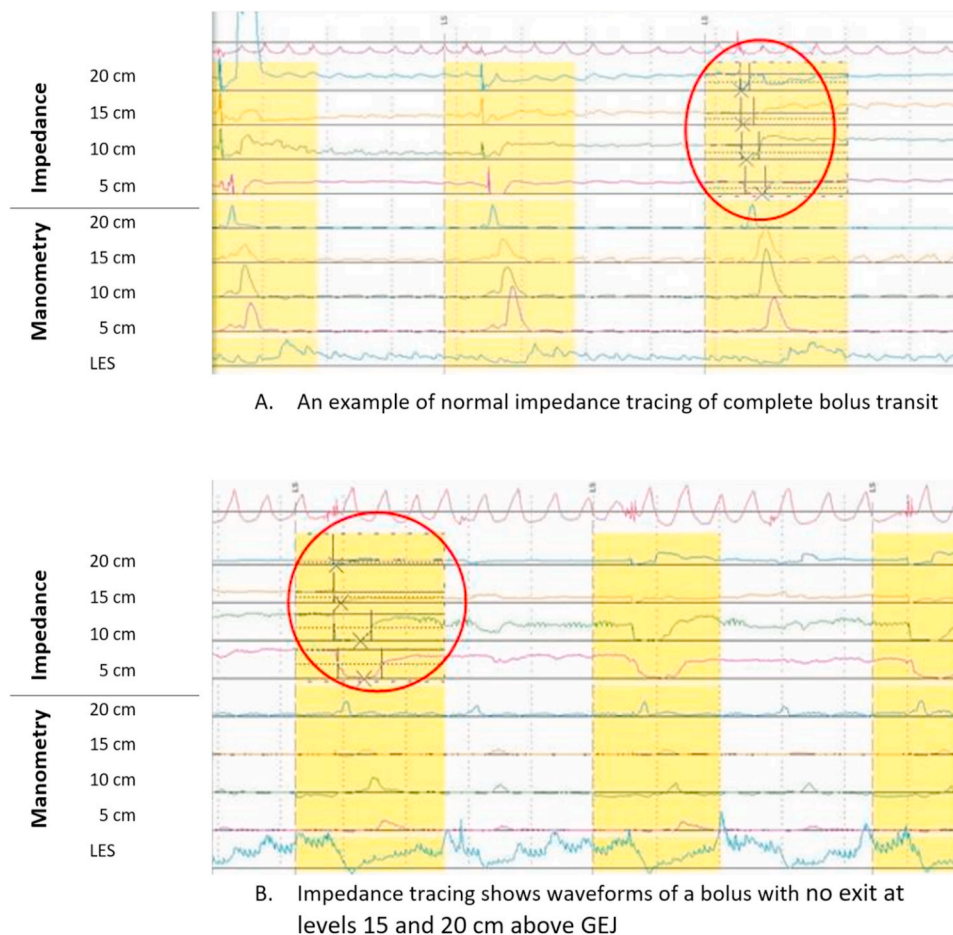
position. We calculated the bolus transits at four esophageal levels of target; at 20, 15, 10, or 5 cm proximal to the gastroesophageal junction (GEJ).

A normal EFT for a liquid swallow is considered when $\geq 80\%$ of a swallow is completed whereas a normal EFT for a viscous swallow is considered when $\geq 70\%$ of a swallow is completed. We consider a bolus transit as abnormal if there is a bolus entrance without a bolus exit after 120 s. A bolus exits of $< 50\%$ was considered as an incompletely transmitted swallow. The site of bolus transit impairment was recorded according to the channel at which the abnormal event occurred. An example of impedance tracing for normal versus abnormal bolus transit is depicted in Fig. 1.

For each participant, we calculate the proportion of abnormal results as the number of abnormal results divided by the total number of each type of swallow (liquid versus viscous). The same is done for calculating the proportion of other outcomes. The LES pressure was measured by using a Koenigsberg 9-channel probe (Sandhill EFT; Sandhill Scientific Inc.; Highlands Ranch, CO). We analyzed the manometric and impedance data using the BioView Analysis (Sandhill Scientific) software. We reported data of LES pressure as mean and standard deviation (SD).

The report of our study is in line with the STROCSS criteria [6]. This study was also registered in Research Registry with a unique identifying number (UIN: researchregistry6651) and publicly accessible via:

<https://www.researchregistry.com/browse-the-registry/#home/registrationdetails/604d356b35d69f001bc74d59/>



LES: lower esophageal sphincter, GEJ: gastroesophageal junction

Fig. 1. Impedance tracing and waveforms in normal (A) and abnormal (B) bolus transit. LES: lower esophageal sphincter, GEJ: gastroesophageal junction.

3. Results

Data of a total of 119 patients over a 12 month-period were reviewed; 57 were male (48%). One patient could not tolerate catheter insertion because of severe gag reflex and was then excluded from the final cohort, hence only 118 patients were included in the analysis. The documented presenting symptoms for patients who were referred to undergo the EFTs were variable, and patients may have more than one complaint at a time. Most of patients reported to have dysphagia (n = 56; 48%) and/or heartburn (n = 53; 44%) as the main presenting complaint. Other symptoms at presentation at the time of referral include chest pain (n = 29; 35%), regurgitation (n = 21; 18%), epigastric pain (n = 12; 10%), nausea (n = 6; 5%), cough (n = 4; 3%), sore throat (n = 2; 2%), and shortness of breath (n = 1; 1%). The reported diagnosis and presenting symptoms of each EFT are summarized in Table 1.

The results of EFT were normal manometry in 63 patients (53.4%); non-specific motility disorder in 14 (11.9%); achalasia in 12 (10.2%), ineffective esophageal motility (IEM) in 7 (6%); and other diagnoses such as GERD, distal esophageal spasm, tight Nissen, isolated hypertensive LES, constituted the remaining 22 patients (18.5%). The mean LES pressure was 24 ± 13.9 mmHg (mean \pm SD) [the normal range is 10–45 mmHg], whereas analysis of esophageal contraction amplitude revealed a mean of 84 ± 46.6 mmHg [the normal range is 30–180 mmHg].

118 patients had liquid swallows whereas 117 had viscous swallows. A total of 2358 swallows was reviewed. Of those 2358 swallows, 837 (35.5%) were incompletely transmitted: 326 (39%) were at 20 cm, 343 (41%) at 15 cm, 131 (15.6%) at 10 cm, and 37 (4.4%) at 5 cm above the GEJ.

3.1. Liquid swallows

Liquid swallows were completed in 118 patients. Of these, 64 (54.2%) had normal results (Group A) and 54 (45.8%) were abnormal (Group B). Group A had 79 abnormal liquid bolus transit at channels 15 and 20 cm, and 17 abnormal liquid bolus transit at channels 5 and 10 cm; while group B had 230 and 80 abnormal bolus transit at channels (15 and 20 cm) and (5 and 10 cm) respectively (Fig. 2).

3.2. Viscous swallows

Viscous swallows were completed in 117 patients. Of these, 55 (47%) had normal results (Group C) and 62 (53%) were abnormal (Group D).

Table 1
Diagnoses and presenting symptoms.

	N	%
Patients, total	118	100%
Diagnosis		
Normal	63	53.4
Non-specific motility disorder	14	11.9
Achalasia	12	10.2
IEM	7	6
Nutcracker	4	3.3
Others	18	15.2
Presenting symptoms		
Dysphagia	56	48
Heartburn	52	44
Chest Pain	29	25
Regurgitation	21	18
Epigastric pain	12	10
Nausea	6	5
Cough	4	3
Sore throat	2	2
SOB	1	1

N: Number; %: percentage; IEM: ineffective esophageal motility; SOB: Shortness of breath.

Group C had 65 abnormal bolus transit at channels 15 and 20 cm, and 13 abnormal bolus transit at channels 5 and 10 cm; while group D had 303 versus 46 abnormal bolus transit at channels (15 and 20 cm) versus (5 and 10 cm) respectively (Fig. 2).

4. Discussion

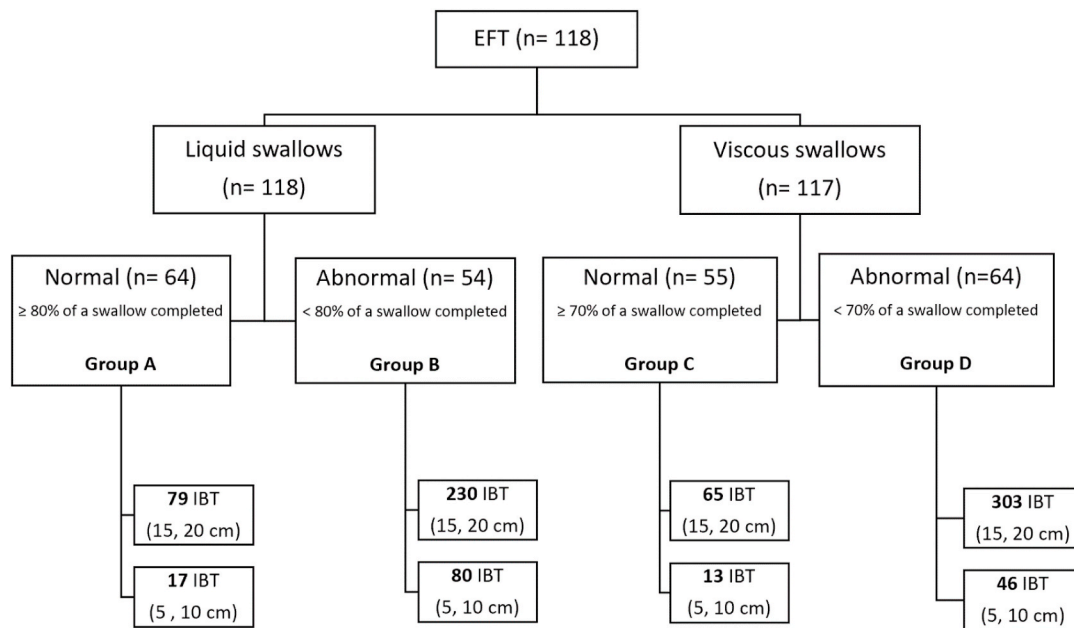
The principal finding of this study is that it identifies a common location of the impaired esophageal bolus transit. We found that most of the impaired bolus transits in patients with symptoms of esophageal dysmotility occurred at the levels of 15 and 20 cm above the GEJ; in more than 80% of the study population irrespective of the underlying diagnosis.

This site of the esophagus encompasses the transitioning zone of striated muscles to smooth muscles, which could be a plausible explanation of dysmotility at first glance. Besides, healthy individuals with the perception of esophageal bolus transit may have physiological alterations at this level. A recent study conducted on healthy participants by Costa et al. concluded that the perception of bolus transit was associated with changes in proximal esophageal motility [7]. Yet, it remains unknown whether these changes are related to the transitioning of muscle types or related to the sensitivity of receptors in proximal esophageal mucosa which activate and mediate peristalsis [8]. Similarly, causation cannot be drawn from our results although correlation with muscle transitioning zone exists. We acknowledge that the scope of our study was not aimed to investigate the underlying causes, rather merely to localize the levels at which impairments occur. Indeed, future studies are necessary to explore and explain these findings.

The exact long-term clinical impact of impaired bolus transit is unclear. The impaired bolus transit may affect esophageal emptying and clearance of saliva which can result in prolonged acid contact, and ultimately the emergence of reflux-related symptoms [9]. Thus, it is important to identify the level at which this impaired bolus transit occurs so as to understand upper GI symptoms and explore potential underlying pathology. EMDs are not common, with a reported annual incidence of 1 per 100,000 individuals worldwide [10,11], but the chronic consequences of these disorders can significantly impact patients' functional status and quality of life. The exact etiology of EMDs is undetermined and possible causes include autoimmune disorders, infections, neurodegenerative conditions, and genetic predisposition [12, 13]. Because EMDs share an overlapped clinical presentation, it can be challenging for physicians to differentiate one disease from the other.

Our retrospective observational study provides an overview of the importance of performing EFT (integration of manometry and impedance) in EMDs which ultimately enhances the diagnostic value. To perform this technique, impedance rings are simultaneously placed around each pressure sensor on a traditional manometry catheter. When a bolus moves through the esophagus, it generates waveforms. Once the bolus volume increases, impedance drops in that segment of the esophagus until the bolus exits; at which point impedance tracing returns to baseline [14]. The role of MII in evaluating bolus transit and gastroesophageal reflux was early explained in 1990 by Silny et al. [15]. Although less frequently performed, EFT encompassing impedance is now considered as a more sensitive diagnostic modality for evaluating the esophageal motor functions when compared with conventional manometry alone [16,17].

A few limitations warrant mention and should be considered when interpreting the results of this study. First, the sample size is relatively small and was based on a single center, which may limit generalizability. Secondly, extra data from clinical follow-ups or assessments of patients with the impaired bolus transit were missing. Nonetheless, the results represent an impetus for understanding the role of MII when evaluating esophageal dysmotility in a broader range of clinical presentations and for promoting future initiatives to enhance esophageal diagnostic modality.



EFT: esophageal function test, n: number of patients, IBT: impaired bolus transit. Bolus transit is measured at 5, 10, 15 and 20 cm above the gastroesophageal junction (GEJ).

Fig. 2. Esophageal functioning testing of the entire cohort.

EFT: esophageal function test, n: number of patients, IBT: impaired bolus transit. Bolus transit is measured at 5, 10, 15 and 20 cm above the gastroesophageal junction (GEJ).

5. Conclusion

The levels of impaired bolus transit appeared to be more common at certain locations in the esophagus than the others. The most common levels at which impaired bolus transits occurred in our study were 15 and 20 cm above the GEJ. This level of the esophagus should be considered in future studies evaluating the pathophysiology of esophageal dysmotility.

Ethical Approval

Anonymous data were used. No ethical approval was needed.

Funding

No funding was received for the study.

Author contribution

Faiz Tuma was responsible for the study design, data collection and analysis, drafting of the manuscript, interpretation of results, revising the final manuscript. Jafar Aljazeera was responsible for data analysis, interpretation of the results, designing figures and tables, and revising the final manuscript. Zhamak Khorgami interpreted data and critically revised the manuscript. Leena Khaitan: conceptualized the research project, study design, critically revised the manuscript and supervised the flow of the study.

Consent

NA.

Registration of Research Studies

Anonymous data were used. No human subjects were involved.

1. Name of the registry: Research Registry
2. Unique Identifying number or registration ID: researchregistry6651
3. Hyperlink to your specific registration: <https://www.researchregistry.com/browse-the-registry#home/>

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Declaration of competing interest

All authors state no conflict of interests.

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The preliminary results of this study were presented as a poster presentation at the Society of American Gastroenterologists and Endoscopic Surgeons (SAGES) and the abstract was published in SAGES abstract archive; program number assigned is P330. No competing financial interests exist.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amsu.2021.102277>.

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