

Assessment of Esophageal Emptying in Patients with Dysphagia: Differences Between High-Resolution Impedance Manometry and Timed Barium Esophagram

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Abstract

Background/Aims: Assessment of esophageal emptying is important in the evaluation of patients with dysphagia. As several modalities can evaluate this, we aimed to compare two tests frequently used for assessing esophageal emptying—high-resolution impedance manometry (HRiM) and timed barium esophagram (TBE).

Methods: A retrospective study compared the results of HRiM and TBE in patients with dysphagia between 2018 and 2022. Abnormal esophageal clearance was defined as $\geq 30\%$ swallows with incomplete bolus clearance on HRiM and as residual barium ≥ 2 cm at 5 minutes on TBE.

Results: 77 patients were included in the study (mean age 51.6; 69% female). The most common HRiM diagnoses were normal motility (37.7%), ineffective esophageal motility (28.6%), and achalasia (19.5%). Effective esophageal clearance was noted on HRiM in only 44 subjects (57.1%), while it was seen on TBE in 57 subjects (74.0%) ($P=0.027$). There was agreement between the studies in 58 subjects (75.3%). Agreement was significantly affected by the HRiM diagnosis with the highest rate (86.7%) among achalasia patients ($P=0.032$). The only other factor correlated to agreement between the studies was a lack of alcohol use ($P=0.048$).

Conclusions: According to the parameters used in this study, TBE is more likely to reveal esophageal emptying than HRiM in patients with dysphagia. While there is fair agreement between the results of the two studies, results are especially concordant in achalasia patients suggesting that either study may be useful in evaluating esophageal emptying in that population. (*Acta gastroenterol belg.*, 2025, 88, 89-95).

Keywords: manometry; impedance; timed barium esophagram; dysphagia; esophageal emptying.

Introduction

Esophageal high-resolution manometry (HRM) is the “gold standard” for the diagnosis of esophageal motility disorders (1). The advent of HRM catheters has enabled a continuous representation of esophageal pressures and has facilitated a more accurate evaluation of esophageal body and sphincter function.

Multichannel intraluminal impedance (MII) sensors were added to manometry catheters over 20 years ago. Initial studies using fluoroscopy validated impedance as a means of detecting bolus movement and clearance (2-4). Early clinical studies also showed that MII could correlate with esophageal pressures and display poor bolus clearance in certain motility disorders such as achalasia (5-7). However, in a study by Conchillo et al of achalasia patients, MII

was found to not correlate well with bolus clearance when compared to barium fluoroscopy (8).

More recent studies using impedance measurements during HRM, known as high-resolution impedance manometry (HRiM), have tried to correlate impedance findings with barium studies to evaluate bolus clearance (9-12). However, these studies all relied on the use more advanced statistical calculations to interpret impedance rather than a standard interpretation by the interpreter evaluating if the color contour disappears after a swallow. Thus, the standard interpretation of impedance for bolus clearance has not been well correlated with bolus clearance in HRiM studies and its clinical utility is not clear. Currently, impedance assessment is not part of the Chicago classification (13).

During the era of the development of impedance, a new radiological test for measuring esophageal emptying has also been developed, the timed barium esophagram (TBE). TBE was initially used to evaluate esophageal emptying after treatment of achalasia. Studies showed that TBE correlated with clinical response to pneumatic dilation and predicted long-term success of treatment (14,15). Nowadays, TBE is also used to evaluate esophageal clearance in other situations such as untreated achalasia and esophagogastric outlet obstruction (EGJO) (13-16).

Despite the increase in studies assessing TBE, studies correlating it to standard impedance findings are lacking. Therefore, we aimed to assess bolus retention using both HRiM and TBE in a cohort of patients with esophageal dysphagia, and to determine the agreement between these two modalities on quantifying bolus retention and clearance. Secondly, we evaluated which clinical and manometric factors impacted the correlation between these two modalities.

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Methods

Study design

This is a retrospective study at a single tertiary care medical center. Data was collected from the electronic medical records of all adult patients (over the age of 18) who underwent both HRiM and TBE as part of their evaluation of dysphagia between 2018 and 2022. Both procedures had to be performed within 3 months of each other to be included in the study. Details including demographics, medical and surgical history, medications, and endoscopy findings were recorded.

Patients were excluded if they had: prior upper gastrointestinal surgery; prior endoscopic intervention to the esophagus such as a dilation or Botox injection; significant comorbidities that could affect esophageal motility (such as a history of radiation to the chest, caustic ingestion, chemotherapy, Parkinson's disease, scleroderma, mixed connective tissue disorder, systemic lupus erythematosus, thyrotoxicosis, myxedema, Chagas disease, amyloidosis or sarcoidosis); opiate use; technical failure or inability to complete either the HRiM or TBE study; or data missing from their chart. Additionally, any patient with findings on upper endoscopy to explain their dysphagia symptoms, such as a ring, stricture, or eosinophilic esophagitis, was excluded.

HRiM parameters

HRiM studies were performed using the Manoscan system (Medtronic, Minneapolis, MN, USA). The study protocol was performed according to the Chicago Classification criteria with at least 10 interpretable supine wet swallows (13). Bolus transit was assessed for each individual swallow of 5 ml water during supine position using colored contour function of the Manoview software. Bolus passage during HRiM was defined as the complete disappearance of the intra-esophageal bolus on impedance manometry, whereas retention of material in the esophagus was defined as persistent colorization within the esophagus after the swallow (17,18). Abnormal clearance was defined as $\geq 30\%$ of swallows with residual esophageal retention as has been previously described (19-21). All diagnoses of esophageal motility disorders were given as per the Chicago Classification criteria, version 4.0 (13). All studies were interpreted by an expert in neurogastroenterology and esophageal motility disorders (A.M.).

TBE parameters

TBE studies were performed according to the standard protocol of the patient drinking 200-250 ml of low-density (45% weight to volume) barium sulphate with subsequent images taken after 1, 2, and 5 minutes

(16). Any residual barium was reported by measuring the height of the barium column. Normally, the barium fluid is cleared within 1-2 minutes from the esophagus. In contrast, the typical finding in untreated achalasia is residual barium persisting in the esophagus even after 5 minutes. As there are no standardized values for TBE in patients with non-achalasia dysphagia (16), the standard practice of radiologists in our area is to report on the presence of residual barium on the 5-minute x-ray. A residual barium column ≥ 2 cm after 5 minutes was considered abnormal esophageal clearance. The TBE studies were performed in several medical centers in the region and all reports were signed by an expert radiologist.

Ethics and Informed Consent

The study was approved by the medical center's Institutional Review Board. The study was exempted from the need for informed consent as the research was retrospective and all data was de-identified.

Statistical Analyses

Continuous variables are reported as Mean $\pm$ SD and Median $\pm$ IQR. Categorical variables are reported as proportions. Univariate analyses were performed using Chi-Square for categorical variables. For continuous variables, parametric tests such as independent t-test and one-way ANOVA were used, and non-parametric tests such as Mann-Whitney if the distribution of data is not normal. Kolmogorov test was used to examine data of the normal distribution. The association measures will be reported as odds ratios between the Outcome and Exposure. The statistical significance (alpha error) was defined at 0.05.

Results

Clinical characteristics and manometric findings of the study cohort

Overall, 77 subjects were included in the study. Table 1 demonstrates demographics and baseline characteristics of the study cohort. The average age of the cohort was 51.6 ± 15.3 with 69% being women. Most of the patients did not have an underlying neurological disease (74%).

On high resolution manometry, the most common diagnosis was normal motility in 37.7%. Other common diagnoses included ineffective esophageal motility (28.6%), achalasia (19.5%), and EGJOO (7.8%). The mean integrated relaxation pressure (IRP) was 11.6 ± 13.2 .

Table 1. — Baseline characteristics and manometric findings of the study cohort.

Number of patients	77
Age, mean $\pm$ SD (years)	51.6 $\pm$ 15.3 (18-76)
BMI, mean $\pm$ SD	32.2 $\pm$ 3.3 (23-41)
Gender, N (%)	
Male	30 (39)
Female	47 (61)
Ethnicity, N (%)	
Jewish	38 (49.4)
Arab	39 (50.6)
Neurological disorders, N (%)	
None	57 (74)
Cerebrovascular accident	19 (24.7)
Parkinson	0
Multiple sclerosis	1 (1.3)
Chest surgery, N (%)	1 (1.3)
Thyroid disease, N (%)	15 (19.5)
Ischemic heart disease, N (%)	9 (11.7)
Diabetes mellitus, N (%)	14 (18.2)
Smoking, N (%)	19 (24.7)
Alcohol use, N (%)	5 (6.6)
Tricyclic antidepressant use, N (%)	4 (5.2)
Selective serotonin reuptake inhibitor use, N (%)	3 (3.9)
Non-steroidal anti-inflammatory drugs use, N (%)	22 (28.6)
H2 Blocker use, N (%)	3 (3.9)
Proton pump inhibitor use, N (%)	54 (70.1)
Manometric diagnosis, N (%)	
Normal motility	29 (37.7)
Ineffective esophageal motility	22 (28.6)
Achalasia	15 (19.5)
Esophagogastric outlet obstruction	6 (7.8)
Absent contractility	2 (2.6)
Distal esophageal spasm	2 (2.6)
Hypercontractile esophagus	1 (1.3)
IRP, mean $\pm$ SD	11.6 $\pm$ 13.2 (0-72)
Symptoms during rapid drinking challenge, N (%)	23 (30.3)
Clearance on HRiM, N (%)	44 (57.1)
Clearance on TBE, N (%)	57 (74.0)
Agreement between HRiM and TBE clearance, N (%)	58 (75.3)

Esophageal emptying per HRiM and TBE

HRiM and TBE studies were evaluated for esophageal clearance. Esophageal clearance was noted on HRiM in only 44 subjects (57.1%), while it was seen on TBE in 57 subjects (74.0%) ($P=0.027$). Agreement between the results of esophageal clearance on HRiM and TBE was seen in 58 subjects (75.3%).

Table 2 shows the results of HRiM and TBE for the evaluation of esophageal clearance based on manometric diagnosis. Differences were noted based on the underlying motility diagnosis. For example, esophageal clearance was seen in the majority of patients with normal motility (86.2% on HRiM and 89.7% on TBE). In contrast, clearance was only noted in a minority of achalasia patients (0.0% on HRiM and 13.3% on TBE).

Logistic regression analysis of parameters associated with agreement between esophageal clearance on HRiM and TBE

Table 3 demonstrates logistic regression analysis of parameters associated with agreement between the findings of esophageal clearance on HRiM and TBE. Of the medical conditions, lack of alcohol use was found to be associated with correlation between the studies (only 40.0% agreement in alcohol users, but 78.9% agreement in non-drinkers; $p=0.048$). No differences were noted in the rates of agreement according to medication use including proton pump inhibitors ($P=0.70$), tricyclic antidepressants ($P=0.98$), selective serotonin receptor inhibitors ($P=0.31$), and non-steroidal anti-inflammatory drugs ($P=0.15$).

Table 2. — Esophageal emptying per HRiM and TBE according to manometric diagnosis.

Manometric Diagnosis	Emptying on HRiM	Emptying on TBE
Overall cohort, (77 patients)	44 (57.1)	57 (74.0)
Normal motility, (29 patients)	25 (86.2)	26 (89.7)
Ineffective esophageal motility, (22 patients)	18 (81.8)	22 (100)
Achalasia, (15 patients)	0 (0.0)	2 (13.3)
Esophagogastric outlet obstruction (6 patients)	0 (0.0)	4 (66.7)
Absent contractility (2 patients)	0 (0.0)	1 (50.0)
Distal esophageal spasm (2 patients)	0 (0.0)	1 (50.0)
Hypercontractile esophagus (1 patient)	1 (100)	1 (100)

Table 3. — Comparison of parameters among patients with and without agreement concerning esophageal clearance between their HRiM and TBE studies.

Agreement between HRiM and TBE clearance		P value
	Yes	
Gender, N (%)		0.39
Male	21 (70)	
Female	37 (78.7)	
Ethnicity, N (%)		0.84
Jewish	29 (76.3)	
Arab	29 (74.7)	
Neurological disorders, N (%)		0.84
None	43 (75.4)	
Cerebrovascular accident	14 (73.7)	
Parkinson	0	
Multiple sclerosis	1 (100)	
Chest surgery, N (%)		0.56
No	57 (75)	
Yes	1 (100)	
Thyroid disease, N (%)		0.26
No	45 (72.6)	
Yes	13 (86.7)	
Ischemic heart disease, N (%)		0.068
No	49 (72.1)	
Yes	9 (100)	
Diabetes mellitus, N (%)		0.75
No	47 (74.6)	
Yes	11 (78.6)	
Smoking, N (%)		0.42
No	45 (77.6)	
Yes	13 (68.4)	
Alcohol use, N (%)		0.048
No	56 (78.9)	
Yes	2 (40)	
Tricyclic antidepressant use, N (%)		0.98
No	55 (75.3)	
Yes	3 (75)	
Selective serotonin reuptake inhibitor use, N (%)		0.31
No	55 (74.3)	
Yes	3 (100)	
Non-steroidal anti-inflammatory drugs use, N (%)		0.15
No	39 (70.9)	
Yes	19 (86.4)	
H2 Blockers use, N (%)		0.31
No	54 (74)	
Yes	3 (100)	
Proton pump inhibitor use, N (%)		0.70
No	18 (78.3)	
Yes	40 (74.1)	
Symptoms at rapid drinking challenge, N (%)		0.66
No	39 (73.6)	
Yes	18 (78.3)	

Table 4. — Agreement between HRiM and TBE for esophageal clearance based on manometric diagnosis.

Manometric diagnosis, N (%)	Agreement between HRiM and TBE clearance		P value
	No	Yes	
Normal motility, (29 patients)	7 (24.1)	22 (75.9)	0.032
Ineffective esophageal motility, (22 patients)	4 (18.2)	18 (81.8)	
Achalasia, (15 patients)	2 (13.3)	13 (86.7)	
All other manometric diagnoses, (11 patients)	6 (54.5)	5 (45.5)	

Finally, there were differences in agreement between the studies based on the manometric diagnosis according to the Chicago classification, version 4.0 (Table 4). For example, achalasia had a higher agreement rate between HRiM and TBE (86.7%) than ineffective esophageal motility (81.8%), normal motility (75.9%), or any other diagnosis (45.5%)($P=0.032$).

Discussion

Our study attempted to evaluate the agreement between two different methods of evaluating esophageal clearance in patients with dysphagia. We found that the results of HRiM and TBE were in agreement in 75.3% of cases.

Objective measurements of esophageal emptying are important in evaluating patients with obstructive esophageal diseases. They have mainly been studied in patients with achalasia (14,15,22). The post-treatment response among patients with achalasia can be assessed with TBE or HRM (23). A seminal study of TBE evaluated achalasia patients after pneumatic dilation (15). This study found that patients with poor barium clearance on TBE, even though they were asymptomatic, were more likely to have treatment failure at their 1-year follow-up appointment and require repeat therapy. HRM is also often used to evaluate achalasia patients after therapy with a focus on the IRP measurement (23). Studies often use an IRP <10 mmHg as a sign of adequate treatment (24,25). IRP post-treatment has also been shown to correlate with clearance on TBE (22). However, impedance on HRiM is frequently not used in the evaluation of post-treatment achalasia patients.

Part of the confusion regarding the evaluation of esophageal clearance is that there is no “gold standard” test. If there were, then other tests of esophageal clearance could be compared to it. While TBE has evidence to support its use in achalasia patients post-therapy, the evidence of its utility in other situations, such as in evaluating uninvestigated dysphagia or in patients with manometric EGJOO, is less clear (16). The utility of HRiM is also unclear and its impedance component is not a part of the Chicago classification (13).

Part of the difficulty in comparing these two tests is that they are performed in distinct manners. HRiM is performed with water swallows in a supine position with each individual bolus being assessed individually

within seconds of the swallow. On the other hand, TBE is evaluated by drinking barium in an upright position and allowing up to 5 minutes to clear it. Thus, the consistencies of the liquids, the length of the study, and the effect of gravity differ between the tests making comparisons difficult. It is precisely because of these inherent differences that we aimed to perform a comparative study assessing the agreement between the results of these studies in evaluating esophageal emptying in patients with dysphagia.

We found that adequate esophageal clearance was only noted on HRiM in 57.1% of cases, compared to a 74.0% clearance rate on TBE. This suggests that HRiM is more likely to show esophageal retention than TBE. While impedance has been shown to correlate with esophageal bolus movement and clearance (2-4), the settings and parameters used to evaluate HRiM may be more “rigid” in comparison to TBE, and thus more likely to consider esophageal bolus clearance as failed. Adjusting the parameters and settings of HRiM may “loosen” this threshold and allow a higher percentage of swallows to be considered adequately cleared.

We found that there was matching between HRiM and TBE in 75.3% of cases. Notably, there was a higher matching rate among achalasia patients (86.7%) compared to ineffective esophageal motility, normal motility, or other manometric diagnoses. This finding is consistent with previous studies of TBE in differentiating between motility disorders. For example, a study by Blonski et al described the TBE findings at 2 minutes and 5 minutes that can be used to distinguish untreated achalasia from confirmed EGJOO or non-achalasia dysphagia (26). Other studies have shown that within achalasia, cases of Type III achalasia have better clearance on TBE than Type I or Type II (27,28). Given the utility of TBE in cases of achalasia, and given the good correlation between TBE and HRiM found in this study amongst achalasia patients, this suggests that HRiM should also be a good study to evaluate esophageal clearance in achalasia patients.

We also found that alcohol use significantly impacted the agreement between TBE and HRiM with alcoholics more likely to have incongruous studies. Alcohol is known to affect esophageal motility (29). For example, alcohol can cause relaxation of the lower esophageal sphincter and decreased esophageal contraction amplitudes when given to healthy controls, while chronic alcoholics were shown to have higher esophageal contraction amplitudes compared to controls

(30). Despite this, it remains unclear why alcohol would have differently affected esophageal clearance on HRiM versus TBE in our study. Most probably this is a coincidental finding given the very small number of patients as only 5 patients (6.6% of the cohort) had a diagnosis of alcoholism. There are also obvious limitations to this since, given the retrospective nature of the study, we could not prospectively assess the frequency and level of alcohol intake of all the subjects.

While not the focus of this study, EndoFLIP is another test that can assess esophageal motility and EGJ opening. Studies have shown that the distensibility index (DI) in achalasia patients correlates with emptying in TBE studies (31,32). Thus, DI may provide some correlation to bolus clearance in achalasia patients. Studies comparing DI to bolus clearance in HRiM and TBE in other clinical scenarios may be worth investigating.

Our study has some limitations. While both the impedance component of HRiM and TBE are frequently performed to evaluate esophageal clearance in a wide range of clinical settings, neither is truly a “gold standard,” and thus we are unable to comment about which test is more accurate. Additionally, the values and parameters for interpreting esophageal clearance have not been standardized for these tests, and thus the values chosen as cut-offs for our study have not been validated. While we accounted for some medications that may affect esophageal motility, data on other medications such as anticholinergics, calcium channel blockers, and nitrates were unavailable. We identified patients with alcoholism based on that diagnosis in their charts, but could not account for the type, frequency, and amount of alcohol imbibed. Our study was performed at a single medical center and may not be generalizable to other locations. For the achalasia patients, no data on esophageal morphology (straight-type versus sigmoid-type) was available. As the number of subjects without normal motility, IEM, or achalasia was limited, we were forced to combine the other manometric diagnoses together so comparisons could be performed. Given its retrospective nature, not all variables could be assessed, nor could the HRiM and TBE be performed at the same time or location. Finally, since the TBE studies were performed at various centers in the area, we could not control for slight differences in protocol or interpretation that may have occurred.

In conclusion, we found that TBE was more likely to show esophageal emptying than HRiM in a cohort of patients with dysphagia. In three-quarters of cases, there was agreement between the results of the two studies, with an even better correlation in cases of achalasia. This suggests that HRiM, as TBE has already been shown, may be a good test for evaluating esophageal emptying in achalasia patients. Further studies on the optimal assessment of esophageal emptying, the best clinical scenarios to use TBE and HRiM, and the ideal cut-off values for these tests are warranted.

Declarations

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