Received: 26 January 2023 | Revised: 27 March 2023 | Accepted: 11 April 2023

DOI: 10.1111/nmo.14605

REVIEW ARTICLE

Neurogastroenterology & Motility NGM WILEY

How to effectively use and interpret the barium swallow: Current role in esophageal dysphagia

Santosh Sanagapalli[1,2] | Andrew Plumb[3] | Reginald V. Lord[4] | Rami Sweis[5]

[1]Department of Gastroenterology and Hepatology, St. Vincent's Hospital Sydney, Darlinghurst, Australia

[2]School of Clinical Medicine, St. Vincent's Healthcare Campus, University of New South Wales, Sydney, Australia

[3]Centre for Medical Imaging, University College London Hospital, London, UK

[4]Department of Surgery, University of Notre Dame School of Medicine, Sydney, Australia

[5]GI Physiology Unit, University College London Hospital, London, UK

Correspondence
Santosh Sanagapalli, Centre for Swallowing and Oesophageal Disorders, St. Vincent's Hospital Sydney, 390 Victoria St, Darlinghurst, NSW 2010, Australia.
Email: santosh.sanagapalli@svha.org.au

Abstract

Background: The barium swallow is a commonly performed investigation, though recent decades have seen major advances in other esophageal diagnostic modalities.

Purpose: The purpose of this review is to clarify the rationale for components of the barium swallow protocol, provide guidance on interpretation of findings, and describe the current role of the barium swallow in the diagnostic paradigm for esophageal dysphagia in relation to other esophageal investigations. The barium swallow protocol, interpretation, and reporting terminology are subjective and non-standardized. Common reporting terminology and an approach to their interpretation are provided. A *timed* barium swallow (TBS) protocol provides more standardized assessment of esophageal emptying but does not evaluate peristalsis. Barium swallow may have higher sensitivity than endoscopy for detecting subtle strictures. Barium swallow has lower overall accuracy than high-resolution manometry for diagnosing achalasia but can help secure the diagnosis in cases of equivocal manometry. TBS has an established role in objective assessment of therapeutic response in achalasia and helps identify the cause of symptom relapse. Barium swallow has a role in the evaluating manometric esophagogastric junction outflow obstruction, in some cases helping to identify where it represents an achalasia-like syndrome. Barium swallow should be performed in dysphagia following bariatric or anti-reflux surgery, to assess for both structural and functional postsurgical abnormality. Barium swallow remains a useful investigation in esophageal dysphagia, though its role has evolved due to advancements in other diagnostics. Current evidence-based guidance regarding its strengths, weaknesses, and current role are described in this review.

KEYWORDS
achalasia, barium esophagogram, dysphagia, endoscopy, esophageal motility, esophagogastric junction outflow obstruction, high-resolution manometry

1 | INTRODUCTION

The barium swallow (also termed esophagogram) is a long-established and widely used esophageal diagnostic test. Uniquely, it provides information about both esophageal structure and function. However, recent decades have seen significant advances in other esophageal diagnostics; including widespread access to endoscopy with enhanced image quality, major technological advances in assessment of esophageal motor function with development of high-resolution manometry (HRM), and a completely new diagnostic modality in

functional lumen imaging probe (FLIP), measuring esophageal wall response to distension.

The purpose of this review is first, to describe the components of the barium swallow protocol. Second, to provide recommendations regarding interpretation of findings, including limitations of the test. Third, to provide evidence-based guidance regarding the current role of the barium swallow alongside other esophageal tests in the diagnostic paradigm. We focus on the evaluation of esophageal dysphagia, which should be distinguished from oropharyngeal dysphagia by careful history-taking.[1] Suspected oropharyngeal dysphagia is better evaluated using the videofluoroscopic swallow study (also termed modified barium swallow), with pharyngeal automated impedance manometry emerging as an option in specialized centers.[2] Barium swallow has a very limited role in the assessment of gastroesophageal reflux,[3,4] and this is not encompassed in this review.

2 | THE STANDARD BARIUM SWALLOW PROTOCOL

The goals of the barium swallow are to evaluate esophageal structure and function. More specifically, the aims are to evaluate for structural abnormalities, functional anatomy, esophageal contractility and peristalsis, and emptying. While there are many variations between institutions, the following is a typical protocol for the standard barium swallow, focused on evaluation for esophageal dysphagia (Table 1). Evaluation of the oral cavity, and pharynx is usually performed initially, before continuing with esophageal assessment.

- *Upright*, *single contrast*: The patient is positioned erect, in the left posterior oblique position to avoid obscuration of the esophagus by the vertebrae. The patient is instructed to take sequential swallows of barium. This phase facilitates evaluation of esophageal structural abnormalities including hiatal hernia, strictures, and diverticula.
- *Upright*, *double contrast (optional)*: Patients are instructed to swallow effervescent crystals with a small sip of water, followed by rapid sequential swallows of barium. This allows for simultaneous gaseous distension and mucosal coating. This process facilitates the detection of mucosal abnormalities such as esophagitis and ulcers. Nowadays, this component of the examination is often omitted due to the widespread use of endoscopy, which is more sensitive for these conditions.
- *Prone single swallows*: The patient is repositioned into the prone, right anterior oblique position, and instructed to take sequential, *single*, swallows to assess peristalsis. Barium aliquots of fixed volume (typically 5 or 10 mL) can be efficiently measured and administered orally with a standard syringe. This phase should ideally be assessed using dynamic (video) esophagography to allow for proper assessment of esophageal wall movement and bolus transport. In health, the esophagus should progressively distend to accommodate the bolus, with smooth, progressive primary peristaltic contractions following the tail of the bolus; referred to as a stripping wave. As the bolus reaches the lower esophageal sphincter (LES), sphincter opening is visualized with progressive emptying of contrast into the stomach. Abnormalities that may be observed in this phase include nonprogressive "tertiary" contractions including corkscrew appearance, which may be associated with retrograde bolus passage within the esophagus.
- *Prone*, *repetitive swallows*: Rapid sequential swallows of barium are administered with continuous drinking. This phase maximizes esophageal distension and provides a secondary view of the esophagogastric junction. Proper performance of this phase may permit detection of structural abnormalities missed in earlier phases of the study, especially those in the distal esophagus.

Other provocative tests for gastroesophageal reflux are commonly performed, but their clinical significance is questionable and beyond the scope of this review.

3 | THE TIMED BARIUM SWALLOW

The timed barium swallow (TBS), also known as the timed barium esophagogram, was first described by de Oliveira and colleagues in 1997.[5] Their aim was to develop a simple barium technique that provided a more objective measurement of esophageal emptying in achalasia patients at baseline and following therapy. Being originally designed to evaluate established, rather than suspected, achalasia or undifferentiated esophageal symptoms, it sacrifices providing any meaningful information regarding esophageal wall motion and bolus movement within the esophageal body to improve objectivity of the test. It can be combined with a standard barium swallow study (as described above), with the TBS being performed first wherever possible.

TBS measures esophageal emptying of a column of liquid barium over a 5-min period. Positioned erect, the patient is instructed to drink a fixed amount of barium (usually 200–250 mL with recording of the amount drunk) over 30–60 s. Images of the esophagus are taken at 1, 2, and 5 min post-ingestion.[5] The response in most healthy persons is complete emptying of the esophagus within 1–2 min. In contrast, the typical finding in untreated achalasia is of a residual esophageal barium column standing proximal to the esophagogastric junction, persisting even at 5 min (Figure 1).[6] In such a fashion, measurement of the height and width of any residual barium column at each interval provides an objective, dynamic marker of esophageal emptying at that point in time. The volume of retained barium is usually approximated by measuring its height and width, but more recently, calculation of surface area has been described.[7] Rate of emptying over the 5 min period has also been used as an adjunctive measure, though data are confounded by unmeasured emptying prior to the one-minute image.[7,8] Although patient tolerance can be a confounder, the measurement approach and volume of ingested barium should be kept as consistent as possible to allow accurate comparison over time, for example, following achalasia therapy. For the same reason, it is important to perform

TABLE 1 Components of a barium swallow protocol.

Component	Description	Rationale	Comments
Standard barium swallow			
Upright single-contrast	Sequential swallows of barium in the erect, left posterior oblique position	Initial evaluation of esophageal structure	
Upright double-contrast (optional and commonly omitted)	Swallowing of effervescent crystals and sip of water followed by rapid sequential swallows of barium	Detect mucosal abnormalities by gaseous distension and mucosal coating	Superseded by endoscopy
Prone single swallows	Dynamic images of sequential single swallows of barium in prone, right anterior oblique position	Assess primary peristalsis in conjunction with upright swallowing	Inherently subjective interpretation; esophagographic tertiary waves have poor sensitivity and specificity
Prone repetitive swallows	Rapid, sequential swallows of barium in prone, right anterior oblique position	Evaluate distensibility of esophagus and identify subtle strictures and other structural abnormalities	If performed correctly, can identify strictures missed at endoscopy
Timed barium swallow			
Timed barium swallow (liquid emptying)	200 mL oral barium drunk rapidly whilst erect; images at 1, 2, 5 min with measurement of any residual column of barium above the esophago-gastric junction	Objectively evaluate esophageal emptying	Most robustly studied component, established role in assessment of therapeutic response in achalasia
Solid emptying	13 mm barium tablet, marshmallow, or other barium-soaked solid bolus	Evaluate emptying of solid bolus	Unclear diagnostic thresholds and normative data lacking

the TBS component of a barium swallow study before proceeding to a standard barium swallow where possible, to ensure the volume of barium ingested (and over what period) is known with certainty. In some centers, emptying of solids is also assessed in addition to the conventional liquid TBS protocol, most commonly using either a 13-mm barium tablet or barium-soaked marshmallow or other solid bolus such as bread. Unlike the standard barium swallow, TBS has been demonstrated to be highly reproducible, with low intra- and interobserver variability.[6]

4 | LIMITATIONS OF BARIUM SWALLOW

4.1 | Normative values

A major limitation in barium radiography is the lack of normative data. Standard barium swallow interpretation is largely subjective and overlap of findings in health and disease is common. For example, the presence of esophagographic tertiary waves is common and may be considered normal, especially in persons over age 40; therefore, they are poorly predictive of a significant motor disorder requiring intervention. While TBS is far more objective and reproducible in assessment of emptying, healthy control data are limited to one published paper consisting of only eight subjects.[6] While all of these healthy subjects cleared the esophagus of 250 mL of ingested barium by 2 min, the majority had a residual esophageal column >5 cm at 1 min. There are no normative data for the adjunctive solid emptying component of the TBS using a barium tablet. This is a major limitation hindering interpretation of barium tablet passage, especially as it has also been reported that tablet lodgment occurs in many cases with no identifiable esophageal structural or motor dysfunction.[9]

4.2 | Variability in protocol and reporting terminology

With regards to the standard barium swallow, there is a lack of standardization in the methodology and protocol used for the test, an inherent degree of subjectivity in its interpretation, and variability in the quality of the study often correlating with the degree of expertise of the institution and reporting physician.[10,11] Reporting terminology used in the barium swallow report is also non-standardized and poorly defined, and is therefore prone to being compromised or misinterpreted by the referrer (Table 2). The density of barium preparation may have bearing on the rate of

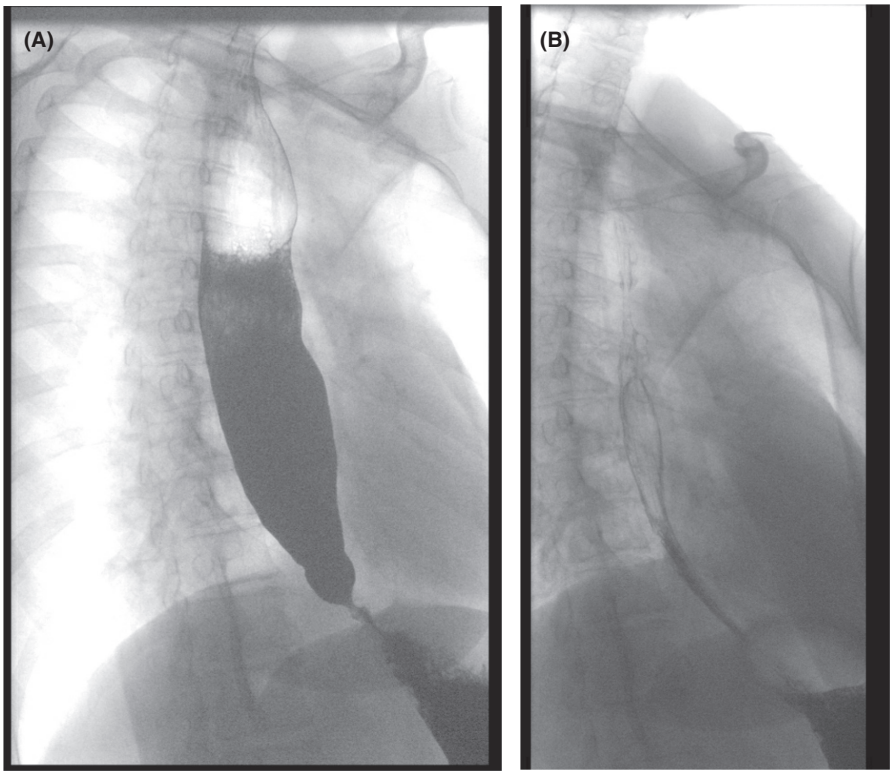

FIGURE 1 Typical timed barium swallow findings in achalasia. At baseline (A), taken 5 min following ingestion of 200 mL barium, a large persistent column of barium remains in the esophagus. In contrast, repeat study following endoscopic myotomy (B) demonstrates essentially complete clearance of barium after only 2 min post-ingestion. This is considered a successful response by radiological criteria and approximates the rate of esophageal emptying seen in health.

emptying yet the preparation used may vary across centers; formulation details are often not reported clinically and in research manuscripts.

5 | UTILITY OF BARIUM ESOPHAGOGRAPHY ALONGSIDE OTHER ESOPHAGEAL INVESTIGATIONS

5.1 | Evaluating for structural causes of dysphagia

A history of solid food dysphagia and/or food bolus impaction raises suspicion for a structural cause of dysphagia.[1,12] Endoscopy is the first-line investigation in this setting. Routine barium swallow prior to endoscopy is not necessary in the initial investigation of such patients, since neither a positive nor negative radiographic examination will preclude the need for endoscopy. Endoscopy not only identifies both malignant and benign strictures of the esophagus, but can also diagnose other anatomic abnormalities and mucosal pathology not easily identified radiographically, such as esophagitis (both reflux and eosinophilic).[12]

However, it is recognized that the sensitivity of endoscopy for the detection of subtle benign strictures is imperfect. This may be particularly the case in eosinophilic esophagitis, where the esophagus is often diffusely narrowed.[13] Where the clinical suspicion for a structural etiology of dysphagia remains despite normal endoscopic appearances, barium swallow may have higher sensitivity to detect subtle webs, rings, and strictures not always visualized at endoscopy.[13–16] For barium swallow to have adequate sensitivity for detection of strictures, adherence to a protocol facilitating adequate distension is essential (e.g., prone repetitive swallows; see Table 1).

5.2 | Establishing diagnosis of achalasia

HRM is the primary method to evaluate esophageal motility and remains the gold standard test for diagnosis of achalasia.[17] In HRM, a catheter comprising multiple pressure sensors is positioned in a fashion so that simultaneous pressure recordings can be made from the hypopharynx to the stomach. HRM pressure data are analyzed according to a consensus schema, the Chicago Classification of esophageal motility disorders, now in its fourth iteration.[17] Per this classification, achalasia is diagnosed when there is manometric evidence of absence of normal peristalsis combined with documented failure of deglutitive LES relaxation, with objective measurement of the latter using a designated HRM metric, the integrated relaxation pressure (IRP); a parameter that measures the esophago-gastric pressure gradient.

The sensitivity and specificity of the standard barium swallow for the diagnosis of achalasia is low compared to HRM. Using the more objective TBS protocol evaluating liquid emptying, its specificity when compared to HRM exceeds 90%, though the sensitivity for diagnosing even clear cut manometric achalasia remains low at 65%–80% using the conventional cut-off of 5 cm at 5 min post ingestion.[9,18–20] Sensitivity of barium swallow is particularly low in Type III achalasia, approximating 25%.[18,19] Although addition of a barium tablet appears to increase the sensitivity of TBS for diagnosing achalasia, this occurs in exchange for reduced specificity, as the tablet may be lodged in a

TABLE 2 Interpreting terminology used in standard barium swallow reports.

Terminology	Interpretation	Approach
Esophageal contractility		
Tertiary waves (Related terms: non-specific "dysmotility," non-propulsive contractions, tertiary contractions, intra-esophageal reflux)	• Non-peristaltic esophageal wall contractions • May be suggestive of motility disorder but can also be seen in health, especially >40 years • In some cases, intra-esophageal reflux (bolus retropulsion) may be observed in association with tertiary waves	If clinical suspicion of esophageal motility disorder exists, perform HRM to definitively evaluate
Corkscrew appearance (Similar terms: rosary bead, spasm)	• More prominent tertiary contractions in distal esophagus • More suggestive, but still not confirmatory, of spastic motor disorder (e.g., achalasia, spasm, hypercontractility)	Perform HRM to confirm presence and type of esophageal motor disorder
Presbyesophagus	• Non-peristaltic esophageal contractions in older patients • No standardized definition • Questionable entity	If clinical suspicion of esophageal motility disorder exists, perform HRM to definitively evaluate
Structural findings		
Dilated esophagus (sometimes termed "mega-esophagus" when particularly dilated >6 cm)	Always pathological, suspect achalasia; however the diameter limit to fulfill this criterion has not been established (3 cm often used arbitrarily)	Perform HRM to clarify diagnosis
Sigmoid esophagus (related terms: S-shaped esophagus, sump formation)	Elongated and tortuous esophagus with axial deviation resembling sigmoid colon. This may cause a sump effect whereby fluid or food debris persistently pools in the "S-bend" of the sigmoid esophagus even following successful lower esophageal sphincter disrupting achalasia therapy	Usually represents end-stage, decompensated achalasia and should be managed as such
Diverticula	Zenker's: posterior hypopharyngeal pulsion diverticulum	Treat if symptoms felt attributable, but may be incidental and asymptomatic if small
	Mid-esophageal or epiphrenic: diverticula in the midportion or distal esophagus, respectively	Evaluate for primary esophageal motor disorder, as there is a strong association especially with epiphrenic diverticula
	Intramural pseudodiverticulosis: innumerable minute, flask-like outpouchings along esophageal wall	Perform endoscopic esophageal dilatation as there is close association with strictures
Lower esophageal sphincter and esophageal function		
Lower esophageal sphincter opens/does not open	Radiologic assessment of sphincter opening extent is not accurate in diagnosis of achalasia and is highly subjective	Perform HRM if there is clinical suspicion of achalasia
Not achalasia	Barium swallow is insufficiently sensitive to exclude achalasia and achalasia has a wide variety of radiological appearances	Perform HRM if there is clinical suspicion of achalasia
Delayed esophageal emptying	Delayed emptying is an abnormal finding but difficult to accurately quantify with a non-standardized barium protocol	Consider TBS to definitively confirm extent of delayed emptying and HRM to evaluate for achalasia or other obstruction
Cervical esophagus		
Cricopharyngeal bar	Persistent posterior indentation of contrast at the level of cricopharyngeus, due to cricopharyngeal fibrosis, reduced compliance and distensibility, but not due to spasm or failed relaxation	Relatively common incidental finding, and should rarely be attributed as cause of dysphagia
Cricopharyngeal spasm (similar terms: cricopharyngeal achalasia or failed UES relaxation)	Misnomer when used to describe radiographically observed incomplete UES opening, since opening and relaxation are not synonymous terms and impaired opening can also occur due to muscle fibrosis and impaired distensibility	True failure of UES relaxation can only be diagnosed with pharyngeal manometry or electromyography
Cervical esophageal web	Thin membrane causing partial obstruction to contrast flow in the proximal esophagus	Webs can often be subtle, incidental findings, but if symptoms are felt attributable to the web then perform endoscopic dilatation
Compression by osteophyte	Compression of the cervical esophagus by anterior osteophytes of the cervical vertebrae	Osteophytes are common but should only be attributed as causing dysphagia if solid bolus is visualized to be delayed or stopped at that level

variety of non-achalasia disorders including esophagogastric junction outflow obstruction, more proximal strictures, narrow caliber lumen, and even psychogenic dysphagia.[9] The primary reason for reduced accuracy of barium swallow is under-recognition of the heterogeneity of radiographic appearances in achalasia. While the dilated body with "bird's beak" esophagogastric junction appearance is most characteristic, achalasia may equally manifest as a corkscrew appearance (especially Type III achalasia) or even normal and non-dilated appearance radiographically (Figure 2).[21]

HRM is, however, not without limitations in the diagnosis of achalasia. It is recognized that HRM may miss some cases of achalasia, as it may sometimes fail to detect impaired LES relaxation, especially where HRM is performed only with standard small volume water swallows.[22] In some cases where HRM fails to demonstrate LES relaxation despite a compatible clinical syndrome for achalasia, failed relaxation has been demonstrated using barium swallow[23] as well as other techniques including FLIP,[24] impedance-HRM[25] and provocative manometric testing.[26,27] Such patients have been demonstrated to respond favorably to achalasia therapies, thus validating the accuracy of diagnosis.[24,28]

Therefore, while it is clear that a normal or negative barium swallow does not exclude the diagnosis of achalasia, it has an important role to play where manometric findings are inconclusive (e.g., absent esophageal body contractility but normal IRP) yet where clinical suspicion of achalasia remains. In this latter situation, characteristic esophageal wall motion abnormalities and/or marked retention of barium on TBS could be used to secure the diagnosis (Figure 3).

5.3 | Assessing therapeutic response in achalasia

Symptoms alone can be unreliable in assessing the therapeutic response to achalasia therapies, and objective measurement of improvement in esophageal emptying is recommended.[29] Assessment of therapeutic response was the initial indication for TBS, and remains its most well-established role (Figure 1). Support for its value in this role was first established by Vaezi et al., who reported that persistent poor esophageal emptying on posttherapy TBS predicted a high likelihood of future disease relapse, even when the patient was in symptom remission.[30] Performing posttreatment TBS has become standard practice, and these findings have been subsequently replicated.[31–33] One group found contradictory findings, that is, stasis on posttherapy TBS did not confer an increased likelihood of relapse at 2 years.[34] The conflicting result is most likely due to the very low threshold for defining stasis (any residual barium at 5 min) on the latter study compared to the others which considered up to a 5 cm column at 5 min or as little as >50% improvement in column height following therapy as a successful response. It should also be borne in mind persistence of barium need not wholly be attributed to obstruction, since both a clearing contraction as well as an unobstructed outlet are features observed in normal emptying.

Other investigations can be used in a similar manner to TBS to assess the response to achalasia therapy. Posttherapy resolution of esophageal pressurization during rapid drink challenge performed as part of HRM, or bolus clearance as measured by impedance-HRM, both correlate closely with barium stasis on TBS, and appear to be similarly predictive of long-term symptom relapse.[35–41]

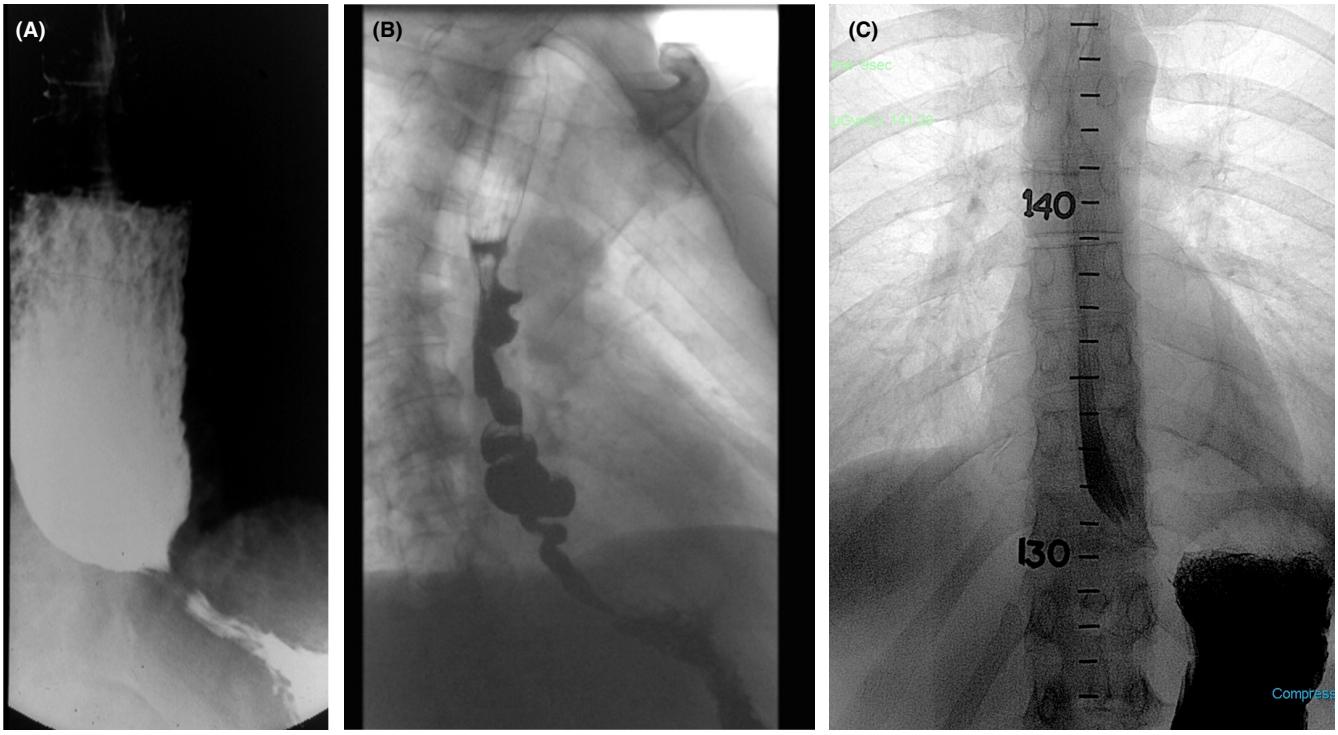

FIGURE 2 Heterogeneity in radiographic appearance of achalasia. While the dilated esophagus with bird's beak is most characteristic (A), achalasia can equally also manifest with a corkscrew appearance (B) and even a relatively normal, non-dilated esophageal morphology (C).

5.4 | Evaluation of long-term symptom relapse following achalasia therapy

Relapse of achalasia requiring retreatment may occur years following successful achalasia therapy of any type. However, in this setting, esophageal symptoms may have several etiologies other than relapse of achalasia.[42] Objective confirmation that symptoms are indeed due to recurrent LES dysfunction is therefore essential before performing further achalasia therapy. Despite use of TBS in this setting being common practice and recommended by society guidelines,[43,44] there is little supporting data for this practice. Rohof et al. systemically assessed 41 achalasia patients who were on average 17 years post therapy, with TBS and conventional manometry.[31] The amount of retained barium on TBS was significantly greater in those with symptom relapse compared to remission (11 vs. 5.5 cm at 5 min). Perhaps more importantly, esophageal stasis >5 cm was highly predictive of any future symptom relapse (positive and negative predictive values 85% and 80%), suggesting that an abnormal TBS is a true marker of recurrent LES dysfunction in patients many years after initial therapy. In contrast, LES pressure measured during manometry did not correlate with symptom relapse at time of assessment and was poorly predictive of future relapse.

While there are few studies specifically evaluating the accuracy of TBS or other diagnostic tests to support treatment decisions in suspected achalasia relapse, its utility remains inherent for several reasons. First, the pathophysiological process underlying achalasia relapse is considered the same as that leading to initial disease onset; therefore, it is logical that TBS should be equally useful in both settings. Furthermore, TBS has several advantages over other tests such as HRM and FLIP. TBS is cheap, widely available, less invasive, free from discomfort, and may provide additional information regarding other causes of symptom relapse unlikely to respond to achalasia therapies. Such causes may include peptic stricture, slippage of the post myotomy antireflux procedure, decompensated esophagus with a sigmoid, dilated, or "sump" morphology, or altered post-myotomy anatomy leading to pseudodiverticulum or an angulated esophagogastric junction causing obstruction (Figure 4).

5.5 | Determining clinical relevance of esophagogastric junction outflow obstruction

Esophagogastric junction outflow obstruction (EGJOO) is a relatively newly defined phenomenon. EGJOO is a high-resolution manometric entity defined by criteria of raised IRP with at least some evidence of intact peristalsis. Manometric EGJOO can correspond to various clinical entities ranging from an achalasia-like syndrome, structural obstruction (e.g., peptic stricture or Schatzki ring) to opiate effect purported to occur via direct effect on opioid receptors in the distal esophagus and LES. Alternatively, EGJOO can be the consequence of an artifact associated with the manometry catheter which is of no clinical relevance. Natural history is unsurprisingly also variable; while many cases are minimally symptomatic or improve without directed therapy, others clinically resemble achalasia and respond to therapies aimed at improving esophageal emptying by disrupting the non-relaxing LES.[45–48]

This often raises a dilemma with regards to clinical decision making. The latest iteration of the Chicago Classification of motility disorders has sought to clarify and standardize the clinical approach to this heterogenous entity, by mandating that additional confirmatory tests are used before consideration of invasive achalasia-type therapies.[17] TBS is one such recommended test that is commonly encouraged in an effort to help discriminate between clinically relevant and spurious manometric EGJOO. There is, however, limited data evaluating utility of TBS in this scenario. Blonski et al. compared TBS

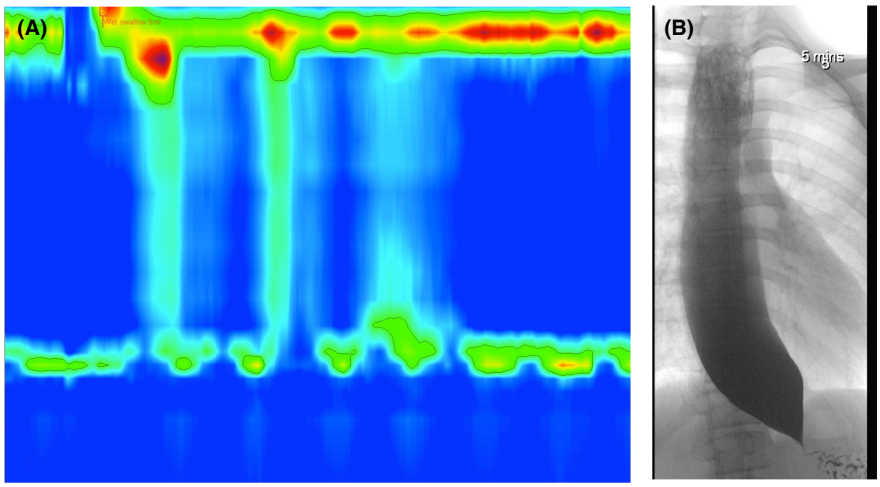

FIGURE 3 Role of barium swallow in achalasia diagnosis. While the sensitivity of barium swallow for diagnosis of achalasia is lower compared to high-resolution manometry, it can sometimes be diagnostic in cases where manometry is inconclusive. In this patient with a typical clinical syndrome of achalasia, endoscopy revealed no mucosal lesion and high-resolution manometry revealed aperistalsis, but failed lower esophageal sphincter relaxation was not demonstrable (A). Therefore, the diagnosis of achalasia was not confirmed. However, further investigation with barium swallow showed markedly delayed emptying of contrast and bird's beak appearance, confirming the diagnosis of achalasia (B). The patient had excellent symptomatic response to pneumatic dilatation of the lower esophageal sphincter.

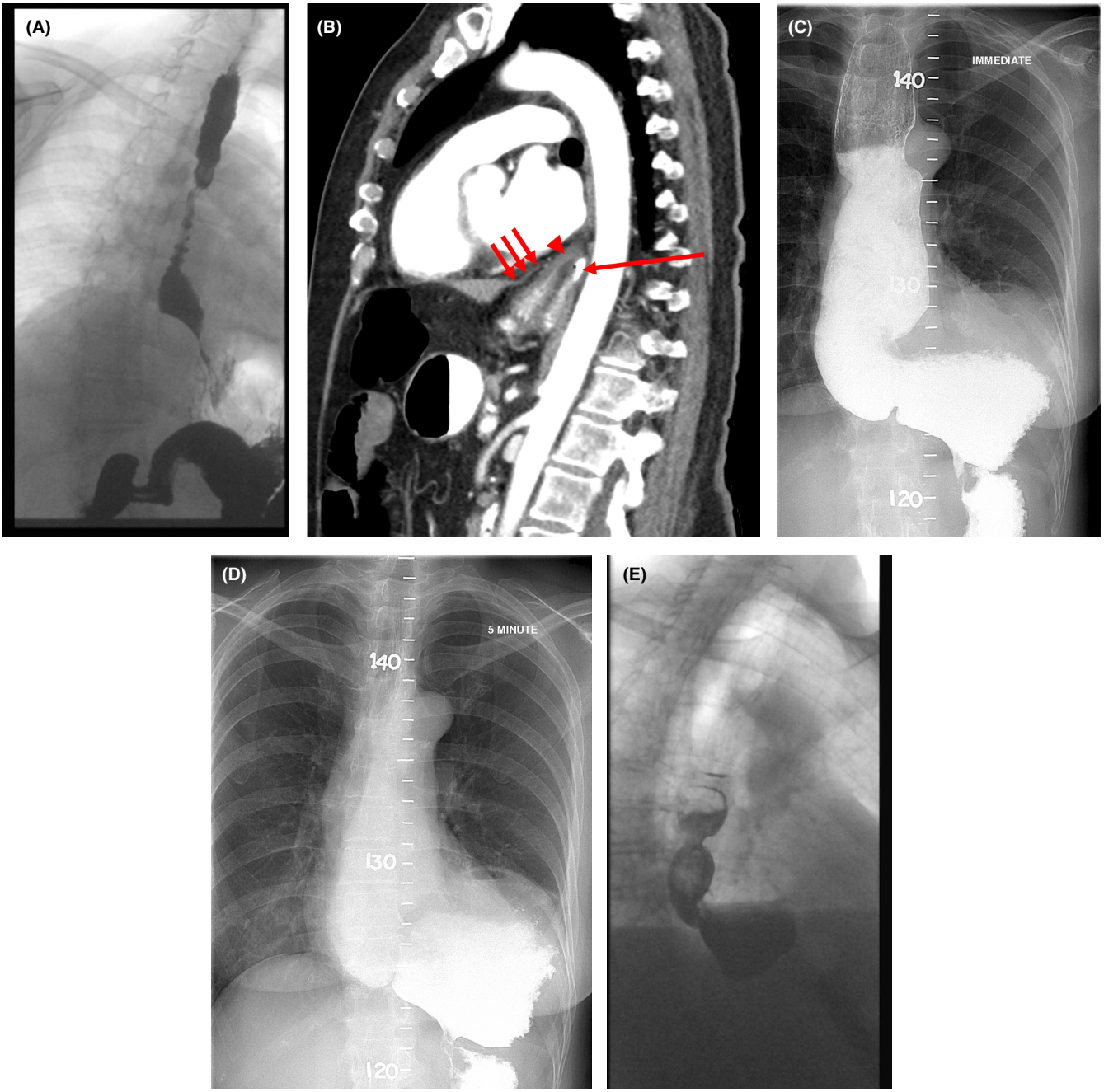

FIGURE 4 Barium swallow in assessment of symptom relapse after achalasia therapy. As well as assessing for true functional relapse of achalasia, barium swallow may identify other structural disorders leading to recurrent symptoms such as slippage of the post-myotomy fundoplication (A), distal esophageal sump (C, D), or diverticulum (E) formation. In (A), barium swallow demonstrates a persistent esophageal barium column terminating abruptly and coincident with a smooth rounded impression on the distal esophagus; CT scan following oral and intravenous contrast (B) confirms that this impression is indeed due to a migrated wrap (arrowhead) clearly seen superior to the diaphragm (short arrows), and compressing the oral contrast in the esophagus (long arrow). (C) demonstrates timed barium swallow immediately after ingestion of 200 mL barium in a patient 30 years post Heller myotomy. A grossly dilated, S-shaped sigmoid esophagus with tall column of contrast in the esophagus is demonstrated. After 5 min (D), most of the vertical column has drained but contrast remains in the baggy "sump," much of which lies lower than the esophago-gastric junction. Fluid and food may continue to pool in such a sump despite adequate disruption of the lower esophageal sphincter, and may be a cause of persistent symptoms. (E) demonstrates an epiphrenic diverticulum.

findings amongst a large cohort of EGJOO and a heterogenous group of "non-achalasia dysphagia"; they found that TBS performed poorly in discriminating these groups (area under curve 0.627; $p = 0.01$) but no attempt was made to determine comparative radiographic characteristics in clinically relevant versus spurious cases of EGJOO.[9]

Clayton et al. reported on 33 patients deemed as having clinically relevant EGJOO based on a positive TBS (which they defined as a 1-min column >4 cm and/or retained barium tablet at 5 min). All underwent pneumatic dilatation, with therapeutic response in greater than two-thirds of the patients (i.e., not a dissimilar response rate to

what would be expected in achalasia), providing some validation of the specificity of a positive TBS to predict EGJOO with true outflow obstruction. However, it is well-recognized that TBS infrequently demonstrates esophageal retention in EGJOO, especially when compared with achalasia.[9,18,49]

Other alternatives for determining the clinical relevance of EGJOO exist. FLIP measuring distensibility of the LES appears to be an accurate tool to identify clinically relevant EGJOO, when assessed against longitudinal clinical outcomes.[50] Provocative testing during manometry using larger volumes of water (rapid drink challenge) or solid food to more closely replicate normal eating and drinking behavior can help clarify the significance of manometric EGJOO. Esophageal pressurization during rapid drink challenge appears to correlate closely with barium retention on TBS.[49] Our group compared the performance of TBS, HRM including rapid drink challenge and a solid test meal, and HRM with small volume water swallows only, in their ability to identify responders to achalasia-type therapies amongst 121 subjects with EGJOO.[51] Again, a positive TBS (here defined as any barium retention >1 cm at 1 min) was highly predictive of clinically relevant EGJOO that responded to achalasia-type therapies, with specificity of 100%. However, the *sensitivity* of TBS for identifying clinically relevant obstruction was relatively poor, at 54%. In this regard it was inferior to manometric findings with the inclusion of a solid test meal, which had a greater sensitivity of 85%. Cumulatively, the limited evidence suggests that a TBS that demonstrates esophageal retention of barium, even at 1 min, is predictive of clinically relevant EGJOO and can be used to support a decision to offer achalasia-type therapy, while a "normal" TBS (i.e., complete esophageal emptying) does not rule out clinically significant obstruction. In such situations further testing, whether by provocative manometric testing or FLIP,[50,52] should be undertaken to ensure that treatable obstruction is not missed.

5.6 | Dysphagia following upper gastrointestinal surgery

5.6.1 | Bariatric surgery

Dysphagia may occur in up to one-third of patients following bariatric surgery such as Roux-en-Y gastric bypass and sleeve gastrectomy.[53] Endoscopy is typically the first-line investigation and may

TABLE 3 How to use barium swallow by clinical scenario.

Clinical scenario	Role of barium swallow and required protocol	Comments	Alternatives
Suspected structural etiology of dysphagia (i.e., solid food dysphagia), but endoscopy negative	Consider standard barium swallow with prone, repetitive swallows	Maximizing esophageal distension is necessary to improve sensitivity of detection of strictures	-
Initial workup of suspected esophageal motility disorder (endoscopy negative)	HRM is preferred and barium swallow not routinely required	In regions without access to HRM, classical radiographic findings of achalasia with a compatible clinical syndrome could be sufficient for diagnosis	-
Suspicion of achalasia but HRM equivocal or non-confirmatory	Standard barium swallow + TBS	Esophageal wall motion abnormalities and/or barium retention at 5 min are supportive of achalasia diagnosis	Provocative manometric testing and/or FLIP could also provide supportive findings
Objective assessment of therapeutic response in achalasia	TBS	Persistent retention of barium post-therapy portends higher likelihood of future relapse	HRM with provocative testing or measurement of bolus clearance can perform a similar role, but is more uncomfortable
Evaluation of suspected achalasia relapse	TBS	Abnormal retention of barium supports retreatment of relapsed disease	HRM can also be used, but is more uncomfortable
Manometric finding of EGJOO	TBS	Positive TBS confirms true outflow obstruction requiring therapy. A negative TBS does not exclude clinically relevant obstruction	Negative TBS should be corroborated with manometric provocative testing and/or FLIP to ensure appropriate therapy is not withheld
Post fundoplication dysphagia	Standard barium swallow + TBS	Evaluate for anatomical defect such as slipped fundoplication and/or recurrent herniation. Stasis of barium above a normal appearing fundoplication may indicate a "too tight" wrap	If no anatomical defect is identified, perform HRM with a solid test meal to identify subtle signs of obstruction at the wrap and/or recurrent herniation
Dysphagia following bariatric surgery	Standard barium swallow + TBS	Evaluate for esophageal wall motion abnormalities, strictures at the esophagogastric junction and/or gastrojejunal anastomosis, and for delayed passage of contrast	-

allow identification of obvious stricturing or other abnormal post-surgical abnormality. However, a secondary achalasia-like pattern has also been reported following bariatric surgery, induced by increased esophageal afterload from a non-compliant and low volume postoperative gastric remnant.[54,55] Therefore, if endoscopic findings are unrevealing, barium swallow is likely to have greater yield by allowing evaluation of postsurgical function as well as structure in such patients. A dilated esophagus or esophageal body contractile abnormalities may be one clue to a secondary achalasia-like syndrome, but abnormal hold up of contrast associated with stricturing at either the esophagogastric junction, gastrojejunal anastomosis, or narrowing of the gastric pouch/remnant itself, could all plausibly account for a perception of dysphagia in the postsurgical setting (and respond to dilatation). Similarly, gastric band placement can be associated with obstruction and motility changes, sometimes difficult to differentiate from true achalasia.[56]

5.6.2 | Post-fundoplication dysphagia

A degree of dysphagia in the early postoperative period is common and is to be expected immediately following any anti-reflux intervention. Early postoperative dysphagia is purported to occur due to surgical edema and/or paralytic "ileus" of the esophagus.[57] It commonly resolves in the majority within the first 3 months.[58]

Persistent or "late" post-fundoplication dysphagia may occur in up to 15%–25% of cases.[59,60] Endoscopy and barium swallow should be performed in all patients with late dysphagia following any form of anti-reflux intervention (e.g., post-fundoplication, magnetic sphincter augmentation, or transoral incisionless fundoplication). This is primarily to evaluate for an anatomical defect such as slipped or mispositioned fundoplication with recurrent hernia, an overly tight crural closure, or fibrosis around the magnetic sphincter mechanism (which may persist even after device removal). If no obvious structural defect is found, HRM can be a useful adjunctive test, having greater sensitivity for detecting small degrees of recurrent herniation associated with minor loosening of the posterior crural repair, which can cause mechanical obstruction at the hiatus.[61] In some cases, no obvious anatomical defect is identified with any of these investigations and dysphagia is attributed to a wrap that is "too tight". Bougie dilatation or even pneumatic dilatation of the wrap to a larger size has been advocated in this situation, though a randomized controlled trial post-fundoplication did not support this strategy.[62] Nevertheless, in the setting of a barium swallow demonstrating marked hold up of contrast of barium at this level or alternatively, outlet obstruction demonstrable on HRM, dilatation of the wrap or magnetic sphincter mechanism could be considered a logical strategy.[63,64]

6 | CONCLUSIONS

The barium swallow remains a frequently used investigation, though one whose role in the assessment of esophageal dysphagia has evolved with advent of other newer diagnostic tests. An appropriate protocol tailored to the clinical situation should be used (Table 3). The TBS is a more well-defined barium protocol which provides more objective and reproducible evaluation of esophageal emptying, and has particular value in the baseline and posttherapeutic assessment of achalasia. Future research should focus on greater standardization of the barium swallow protocol and reporting terminology, and on providing further comparative data against the newer esophageal diagnostic modalities.

AUTHOR CONTRIBUTIONS

Rami Sweis and Santosh Sanagapalli conceptualized the study. SS performed the primary literature review and wrote the initial draft of the manuscript. Andrew Plumb, Reginald V. Lord and Rami Sweis assisted in literature review and critically revised the manuscript.

FUNDING INFORMATION

No external funding.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

DISCLOSURES

No competing interests declare.

ACKNOWLEDGMENT

Open access publishing facilitated by University of New South Wales, as part of the Wiley - University of New South Wales agreement via the Council of Australian University Librarians.

ORCID

Santosh Sanagapalli https://orcid.org/0000-0003-3145-1050

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How to cite this article: Sanagapalli S, Plumb A, Lord RV, Sweis R. How to effectively use and interpret the barium swallow: Current role in esophageal dysphagia. *Neurogastroenterology & Motility*. 2023;35:e14605. doi:10.1111/nmo.14605