Ultrasonographic Criteria for the Noninvasive Diagnosis of Gastroesophageal Reflux Disease: An Evidence-Based Review

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Abstract

Background: Gastroesophageal reflux disease (GERD) is a highly prevalent gastrointestinal disorder encountered frequently in internal medicine practice, with a significant impact on patient quality of life and healthcare utilization. Conventional diagnostic modalities, including upper gastrointestinal endoscopy, 24-hour esophageal pH monitoring, and impedance studies, while effective, are invasive, costly, and not always readily available. These limitations have driven interest in noninvasive, accessible diagnostic alternatives. Ultrasonography has emerged as a promising tool for evaluating gastroesophageal anatomy and reflux dynamics, offering real-time visualization without radiation exposure or patient discomfort.

Aim: This evidence-based review aims to critically evaluate the ultrasonographic criteria that support the noninvasive diagnosis of GERD. The review focuses on the pathophysiologic rationale for sonographic assessment, describes established and emerging ultrasonographic parameters, and appraises their diagnostic accuracy in comparison with standard reference tests. Particular emphasis is placed on clinically applicable criteria relevant to adult internal medicine practice, while also acknowledging pediatric data where applicable.

Methods and Key Findings: Available evidence demonstrates that ultrasonography can identify several GERD-related abnormalities, including visualization of reflux episodes, increased esophageal diameter, impaired lower esophageal sphincter morphology, altered angle of His, and detection of hiatal hernia. Dynamic assessment during provocative maneuvers enhances diagnostic yield. Multiple studies report moderate to high sensitivity for specific ultrasonographic parameters, though specificity varies depending on technique and operator expertise. Ultrasonography shows particular value in patient populations unsuitable for invasive testing and as a screening or adjunctive modality rather than a definitive standalone test.

Conclusions: Ultrasonography represents a valuable, noninvasive adjunct in the diagnostic evaluation of GERD, supported by growing evidence linking specific sonographic findings with reflux pathology. While it cannot replace gold-standard investigations, its safety, accessibility, and real-time assessment capabilities make it an attractive option in selected clinical settings. Standardization of diagnostic criteria, operator training, and high-quality prospective studies are required to define its optimal role in GERD management. This review highlights the potential of ultrasonography to complement existing diagnostic pathways and identifies key gaps for future research.

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Keywords: *Ultrasonographic Criteria, Noninvasive Diagnosis, Gastroesophageal Reflux Disease*

Introduction

Gastroesophageal reflux disease (GERD) is a chronic gastrointestinal disorder characterized by the retrograde movement of gastric contents into the esophagus, leading to troublesome symptoms and/or complications. It represents one of the most common conditions encountered in internal medicine and gastroenterology clinics worldwide, with prevalence estimates ranging from 10% to 30% in Western populations and rising incidence in many developing regions [1]. GERD imposes a substantial burden on healthcare systems due to recurrent outpatient visits, long-term pharmacologic therapy, and evaluation of complications such as erosive esophagitis, Barrett's esophagus, and extraesophageal manifestations.

The diagnosis of GERD is often symptom-based in routine clinical practice; however, symptom assessment alone lacks adequate specificity, particularly in patients with atypical or refractory symptoms. Objective diagnostic tools, including upper gastrointestinal endoscopy and ambulatory esophageal pH or impedance-pH monitoring, are considered reference standards for confirming GERD and assessing disease severity [2]. Despite their diagnostic accuracy, these modalities are invasive, costly, time-consuming, and not universally accessible. Furthermore, patient intolerance and limited availability in low-resource settings restrict their widespread use, highlighting the need for alternative diagnostic approaches.

Ultrasonography has gained increasing attention as a noninvasive imaging modality capable of assessing gastroesophageal anatomy and function in real time. Advances in ultrasound technology and operator expertise have enabled visualization of the distal esophagus, gastroesophageal junction, and dynamic reflux events during physiologic or provoked conditions. Unlike radiographic studies, ultrasonography avoids ionizing radiation and can be repeated safely, making it particularly attractive for vulnerable populations and longitudinal assessment [3].

From a pathophysiologic perspective, several mechanisms underlying GERD—including transient lower esophageal sphincter relaxation, hiatal hernia, and altered esophagogastric junction geometry—are theoretically amenable to sonographic evaluation. Prior studies have proposed multiple ultrasonographic parameters, such as increased esophageal diameter, detection of reflux episodes, abnormal angle of His, and reduced lower esophageal sphincter length, as potential diagnostic markers [4]. However, the heterogeneity of study designs, patient populations, and diagnostic thresholds has limited uniform adoption of these criteria in routine practice.

The existing literature reveals a clear research gap: while numerous studies support the feasibility of ultrasonography in GERD evaluation, there is no widely accepted, standardized set of sonographic diagnostic criteria validated across adult internal medicine populations. Moreover, the diagnostic performance of ultrasonography relative to established reference standards remains variably reported, necessitating a critical synthesis of available evidence.

Aim of the Review: This review aims to provide an evidence-based appraisal of ultrasonographic criteria used in the noninvasive diagnosis of GERD. By integrating pathophysiologic principles, technical considerations, and diagnostic accuracy data, this article seeks to clarify the clinical value of ultrasonography, identify its limitations, and define future directions for research and standardization in internal medicine practice [1–4].

Pathophysiologic Basis of Gastroesophageal Reflux Disease Relevant to Ultrasonographic Assessment

Gastroesophageal reflux disease results from a complex interplay between mechanical, functional, and anatomical abnormalities at the esophagogastric junction. Central to GERD pathogenesis is dysfunction of the lower esophageal sphincter (LES), which normally serves as a high-pressure barrier preventing reflux of gastric contents. Transient lower esophageal sphincter relaxations, rather than persistently low basal LES pressure, are now recognized as the dominant mechanism of reflux in many patients. These transient relaxations allow gastric contents to reflux into the esophagus independent of swallowing and

are closely linked to gastric distension and altered neuromuscular control [5].

Anatomical disruption of the esophagogastric junction, particularly in the presence of a hiatal hernia, further compromises the antireflux barrier. Hiatal hernia leads to separation of the LES from the diaphragmatic crura, reducing the synergistic effect of these structures during respiration. This anatomical alteration increases the frequency and volume of reflux episodes and prolongs esophageal acid exposure. Ultrasonography, by enabling visualization of the diaphragmatic hiatus and relative positioning of the esophagus and stomach, provides a noninvasive means to assess this key pathogenic factor [6].

Another important contributor to GERD pathophysiology is alteration of the angle of His, defined as the acute angle between the esophagus and the gastric fundus. A more obtuse angle reduces the flap-valve mechanism that normally limits reflux, particularly during increases in intra-abdominal pressure. Sonographic assessment of the angle of His has been proposed as a surrogate marker of antireflux barrier integrity, with studies demonstrating a correlation between abnormal angles and increased reflux burden [7].

Esophageal clearance mechanisms also play a critical role in GERD severity and symptom perception. Impaired primary and secondary peristalsis, along with reduced salivary neutralization, prolong mucosal exposure to refluxed contents. Although esophageal motility is traditionally evaluated using manometry, ultrasonography may indirectly reflect impaired clearance through observation of persistent esophageal dilatation or prolonged retention of refluxate in the distal esophagus during dynamic imaging [8].

Gastric factors, including delayed gastric emptying and increased intragastric pressure, further exacerbate reflux events. Postprandial gastric distension increases the likelihood of transient LES relaxations and promotes retrograde flow. Dynamic ultrasonographic assessment after liquid ingestion allows real-time observation of reflux episodes and esophageal filling, linking functional gastric abnormalities with reflux pathophysiology in a physiologic setting [9].

Principles and Techniques of Gastroesophageal Ultrasonography

Ultrasonographic evaluation of the gastroesophageal junction is based on the ability to visualize anatomical structures and dynamic functional events related to reflux in real time. Transabdominal ultrasonography is the most commonly employed approach, owing to its wide availability, safety, and patient tolerability. Using low-frequency convex transducers (typically 2–5 MHz), the distal esophagus, gastroesophageal junction, and proximal stomach can be assessed through the epigastric or left subcostal window. Adequate visualization depends on patient cooperation, operator experience, and optimization of scanning parameters [10].

Patient preparation and positioning are critical to maximizing diagnostic yield. Examinations are usually performed after a fasting period of at least 4–6 hours to reduce gastric content and bowel gas interference. The supine position is commonly used for baseline assessment, while left lateral decubitus or semi-upright positioning may be employed to provoke reflux and improve visualization of reflux episodes. Dynamic maneuvers, such as ingestion of water or milk, abdominal compression, and Valsalva maneuver, are often incorporated to enhance the detection of reflux events and assess esophageal distensibility [11].

Identification of key anatomical landmarks is fundamental to accurate ultrasonographic assessment. The distal esophagus is visualized as a tubular structure posterior to the left lobe of the liver and anterior to the aorta. The gastroesophageal junction is identified by the transition from the esophagus to the gastric cardia, often marked by changes in wall thickness and echogenicity. The diaphragmatic crura can be visualized as hypoechoic muscular structures encircling the esophagus, allowing assessment of their relationship with the lower esophageal sphincter [12].

Dynamic ultrasonography plays a pivotal role in GERD evaluation. Real-time imaging during liquid ingestion enables visualization of retrograde flow of gastric contents into the esophagus, which appears as transient echogenic or hypoechoic material moving cranially. The frequency, duration, and extent of these reflux episodes can be documented and correlated with patient symptoms. Unlike static imaging

modalities, ultrasonography allows repeated assessment over time, improving the likelihood of capturing intermittent reflux events [13].

Technical limitations must also be acknowledged. Ultrasonographic visualization can be compromised in obese patients, individuals with excessive bowel gas, or those with limited ability to cooperate during provocative maneuvers. Additionally, interobserver variability remains a concern due to differences in operator training and interpretation of findings. These factors underscore the importance of standardized scanning protocols and clear diagnostic criteria to improve reproducibility and reliability across clinical settings [14].

Despite these limitations, the principles and techniques of gastroesophageal ultrasonography provide a strong foundation for noninvasive GERD assessment. When performed systematically and interpreted in the context of clinical findings, ultrasonography offers valuable insight into both structural and functional aspects of reflux disease, supporting its role as a complementary diagnostic modality in internal medicine practice [10–14].

Key Ultrasonographic Diagnostic Criteria for Gastroesophageal Reflux Disease

Several ultrasonographic parameters have been proposed to aid in the noninvasive diagnosis of GERD, reflecting both structural abnormalities and dynamic reflux events. Among the most frequently studied criteria is visualization of gastroesophageal reflux episodes themselves. During real-time ultrasonography, reflux is identified as retrograde movement of echogenic or hypoechoic gastric contents from the stomach into the distal esophagus, often occurring spontaneously or following provocative maneuvers such as liquid ingestion or abdominal compression. Repeated visualization of such episodes, particularly when extending several centimeters above the gastroesophageal junction, has been associated with pathologic reflux [15].

Measurement of distal esophageal diameter represents another commonly evaluated parameter. Chronic exposure to refluxate may lead to transient or persistent esophageal dilatation, which can be detected sonographically. Several studies have reported significantly increased esophageal diameters in patients with confirmed GERD compared with healthy controls, suggesting that this finding may reflect impaired clearance or frequent reflux events. Although threshold values vary across studies, an enlarged esophageal diameter has been correlated with abnormal acid exposure on pH monitoring [16].

Assessment of the lower esophageal sphincter morphology is also of diagnostic interest. Ultrasonography allows indirect evaluation of LES length and thickness by identifying the segment of the distal esophagus passing through the diaphragmatic hiatus. A shortened or poorly defined LES segment has been associated with compromised antireflux barrier function. While ultrasonography cannot directly measure sphincter pressure, morphological abnormalities detected on imaging may serve as surrogate markers of LES dysfunction [17].

The angle of His is another important ultrasonographic criterion. A widened or obtuse angle between the esophagus and the gastric fundus diminishes the flap-valve mechanism that normally limits reflux. Sonographic measurement of this angle has demonstrated differences between GERD patients and asymptomatic individuals, with abnormal angles more frequently observed in those with clinically significant reflux. This parameter is particularly relevant in the context of hiatal hernia and altered gastroesophageal junction anatomy [18].

Detection of hiatal hernia is a well-established application of ultrasonography in GERD evaluation. Sonographic features suggestive of hiatal hernia include cranial displacement of the gastroesophageal junction above the diaphragmatic hiatus and separation between the LES and diaphragmatic crura. The presence of a hiatal hernia on ultrasonography has been strongly associated with increased reflux severity and prolonged esophageal acid exposure, reinforcing its diagnostic significance [19].

Additional supportive ultrasonographic findings include prolonged retention of liquid within the distal esophagus following ingestion and increased frequency of reflux episodes during the examination period. While these findings are not specific in isolation, their presence in combination with other criteria enhances diagnostic confidence. Importantly, the use of multiple ultrasonographic parameters rather

than reliance on a single finding improves sensitivity and better reflects the multifactorial nature of GERD pathophysiology [15–19].

Diagnostic Accuracy and Comparison With Reference Standards

Objective confirmation of GERD hinges on endoscopic evidence of reflux-related injury and/or ambulatory reflux monitoring that quantifies abnormal reflux burden. Contemporary guidance emphasizes that endoscopy can provide *conclusive* GERD evidence when erosive esophagitis is present (classically Los Angeles grade C/D, and in updated frameworks grade B in appropriate clinical context), while reflux monitoring off therapy (wireless pH or catheter-based pH or pH-impedance) is preferred when GERD is unproven and symptoms are persistent or atypical. These standards are codified in major practice guidance and consensus statements, which also clarify that symptom response to PPIs alone is not sufficiently specific to establish GERD in many scenarios—hence the continued need for objective testing when diagnostic certainty matters (eg, prior to long-term therapy escalation or antireflux procedures). Ultrasonography must therefore be judged against these reference standards as an **adjunctive** tool rather than a replacement. [20–22]

When compared with reflux monitoring and/or endoscopy, reported diagnostic performance of ultrasonography varies widely because studies differ in (1) scanning approach (transabdominal vs cervical/transcutaneous), (2) provocation protocols (fasting alone vs liquid challenge, abdominal compression, positional change), (3) chosen endpoints (any visualized reflux vs frequency/duration thresholds), and (4) reference standards (endoscopic esophagitis vs pH/pH-impedance). In adult cohorts, transabdominal ultrasonography has been explored primarily as a pragmatic method to visualize reflux episodes or supportive anatomic findings; however, accuracy tends to be **moderate**, with sensitivity often limited when endoscopic esophagitis is used as the comparator—an expected limitation because **non-erosive reflux disease (NERD)** may have normal endoscopy despite clinically significant reflux. One representative adult study evaluating transabdominal ultrasonography against endoscopic findings reported relatively **low sensitivity but higher specificity** when "presence of reflux on sonography" was used to predict reflux-induced esophagitis, underscoring that ultrasonographic reflux visualization may function better as a "rule-in" clue than a definitive diagnostic gatekeeper in adults. [23]

Accuracy improves when ultrasonography targets **anatomical contributors** to reflux that have clearer morphologic correlates, particularly hiatal hernia. For example, transabdominal ultrasonographic measurement of trans-diaphragmatic esophageal diameter has been evaluated as a marker of sliding hiatal hernia, demonstrating high negative predictive value in at least one study when a prespecified diameter threshold was applied and compared with endoscopy confirmation. Clinically, this matters because hiatal hernia is strongly linked to higher reflux burden and more severe phenotypes, and its identification can shift pretest probability, influence the choice of confirmatory testing (pH vs pH-impedance; on vs off therapy), and affect referral decisions for surgical or endoscopic antireflux interventions. [24,20]

A key methodological issue is what constitutes "pathologic reflux" on ultrasound. Brief retrograde flow can occur physiologically, especially postprandially. Some investigators have therefore proposed **time- and frequency-based thresholds** (eg, reflux episode duration and/or number of episodes within a standardized observation period) to better separate physiologic reflux from clinically meaningful GERD. In this regard, work examining structured ultrasound observation windows has suggested that reflux **duration cutoffs** and **episode counts** may improve discriminative ability versus simply documenting the presence/absence of any reflux. However, thresholds are not yet harmonized across studies, and reproducibility between operators and centers remains insufficiently standardized for universal adoption. [25]

Transcutaneous cervical esophageal ultrasonography (TCEUS) has also been studied as a practical approach in adults, focusing on visualization of refluxate and/or surrogate signs of esophageal functional abnormality. Adult data suggest TCEUS can identify refluxate in a meaningful subset of symptomatic patients and may have value as a **pre-diagnostic** screening tool that helps triage who should undergo

formal physiologic testing (eg, impedance-pH monitoring, high-resolution manometry) rather than as a confirmatory stand-alone test. From an internal medicine workflow standpoint, this "triage" role is exactly where ultrasonography can add value—especially when access to physiologic testing is limited or when patient tolerance is a concern. [26,22]

Pediatric evidence is broader and often more favorable, largely because ultrasound avoids radiation and can be repeated, and because protocols frequently incorporate standardized feeding challenges. Studies in infants and children have evaluated measures such as subdiaphragmatic esophageal length, esophageal diameter, diameter-to-length ratios, and dynamic reflux visualization, sometimes reporting higher sensitivities than adult studies—though heterogeneity persists and reference standards vary (pH probe vs clinical diagnosis vs endoscopy). Importantly, pediatric reflux (GER) and pediatric GERD are not identical entities, and interpretation must remain clinically anchored to "troublesome symptoms and/or complications," consistent with consensus disease definitions. This distinction is essential to avoid overdiagnosis when ultrasound detects reflux that is physiologic for age. [27,21]

Clinical synthesis: Against gold standards (endoscopy and reflux monitoring), ultrasonography is best conceptualized as a **complementary, low-risk, readily repeatable modality** that can (1) demonstrate reflux events under standardized conditions, (2) identify anatomic drivers like hiatal hernia, and (3) refine pretest probability to guide whether—and how—to proceed with formal reflux testing. Its principal limitations remain variable sensitivity in adults, operator dependence, and lack of universally validated diagnostic thresholds tied to modern consensus definitions of actionable GERD. [20–23]

Clinical Applications of Ultrasonography in Internal Medicine Practice

In contemporary internal medicine practice, the diagnostic evaluation of gastroesophageal reflux disease increasingly emphasizes rational test selection based on pretest probability, symptom phenotype, and patient-specific factors. Ultrasonography can play a clinically meaningful role at this stage by serving as a noninvasive, readily available adjunct that helps stratify patients before committing them to invasive or resource-intensive investigations. In patients presenting with typical reflux symptoms without alarm features, ultrasonographic findings suggestive of GERD may reinforce clinical suspicion and support initial management decisions, while negative findings may prompt reconsideration of alternative diagnoses [36].

One of the most practical applications of ultrasonography is in patients with **persistent or refractory symptoms** despite empiric proton pump inhibitor therapy. In such cases, ultrasonographic identification of repeated reflux episodes, hiatal hernia, or abnormal gastroesophageal junction anatomy may justify escalation to objective reflux testing, such as ambulatory pH or impedance monitoring. Conversely, absence of supportive sonographic findings may lower the likelihood of pathologic reflux and encourage evaluation for functional heartburn, esophageal hypersensitivity, or non-esophageal causes of symptoms, thereby preventing unnecessary diagnostic procedures [37].

Ultrasonography may also be valuable in patients who are **poor candidates for invasive testing**, including older adults, individuals with significant comorbidities, or those who decline endoscopy or catheter-based monitoring. In these populations, sonographic assessment offers a safe method to obtain supportive anatomical and functional information that can guide clinical decision-making. Although it cannot confirm GERD definitively, the presence of multiple concordant ultrasonographic abnormalities may influence shared decision-making regarding long-term medical therapy or referral for further evaluation [38].

Another important application lies in the evaluation of **extraesophageal manifestations** potentially related to GERD, such as chronic cough, hoarseness, or noncardiac chest pain. These presentations often have multifactorial etiologies and low diagnostic specificity for reflux. Ultrasonography, when used as an adjunctive screening tool, may help identify patients with demonstrable reflux or hiatal hernia who warrant formal reflux monitoring, while reducing indiscriminate testing in patients with low likelihood of reflux-related disease [39].

In outpatient and resource-limited settings, ultrasonography offers logistical advantages that align well

with internal medicine workflows. The ability to perform bedside or clinic-based assessment without sedation, radiation, or specialized equipment allows rapid incorporation into routine practice. When combined with clinical assessment and validated symptom questionnaires, ultrasonography may improve diagnostic efficiency and optimize referral patterns to gastroenterology services [40].

Overall, the clinical utility of ultrasonography in internal medicine is maximized when it is used **strategically**, rather than indiscriminately. Its greatest value lies in refining diagnostic probability, identifying anatomical contributors to reflux, and guiding the appropriate use of confirmatory testing. Integrating ultrasonographic criteria into structured diagnostic pathways may enhance patient-centered care while minimizing unnecessary invasive investigations [36–40].

Limitations and Pitfalls of Ultrasonography in the Diagnosis of Gastroesophageal Reflux Disease

Despite its advantages as a noninvasive and accessible modality, ultrasonography has several inherent limitations that constrain its role in the diagnosis of gastroesophageal reflux disease. One of the most significant challenges is **operator dependency**, as accurate identification of the distal esophagus, gastroesophageal junction, and diaphragmatic crura requires specific training and experience. Variability in probe positioning, interpretation of dynamic findings, and recognition of subtle anatomical landmarks can lead to inconsistent results between examiners and across institutions [41].

Technical factors related to patient characteristics also affect image quality and diagnostic reliability. Obesity, excessive bowel gas, and limited patient cooperation may obscure visualization of the gastroesophageal junction and reduce sensitivity. In addition, respiratory motion and cardiac pulsation can introduce artifacts that complicate interpretation of reflux events, particularly during dynamic assessment. These constraints limit the applicability of ultrasonography in certain patient populations commonly encountered in internal medicine practice [42].

A fundamental diagnostic pitfall is the difficulty in distinguishing **physiologic reflux** from pathologic GERD. Brief episodes of retrograde flow may occur in healthy individuals, especially after meals or during positional changes. Ultrasonography, particularly when relying solely on visualization of reflux, may therefore overestimate disease prevalence if strict diagnostic thresholds are not applied. The absence of universally accepted criteria defining abnormal reflux frequency or duration on ultrasound remains a major limitation [43].

Another important limitation is the **lack of standardized protocols** across studies and clinical settings. Variations in fasting duration, type and volume of liquid challenge, observation time, and patient positioning significantly influence reported diagnostic performance. Without standardized methodology, reproducibility and comparability of ultrasonographic findings remain limited, hindering broader clinical adoption and guideline endorsement [44].

Ultrasonography also provides limited information regarding **mucosal injury and reflux burden**, which are critical components of GERD severity assessment. Unlike endoscopy, it cannot identify erosive esophagitis, Barrett's esophagus, or peptic strictures. Similarly, it cannot quantify acid exposure time or symptom–reflux association, key metrics provided by pH and impedance monitoring. As a result, ultrasonography cannot replace these modalities when precise characterization of disease severity or treatment planning is required [45].

Finally, the existing evidence base is constrained by relatively small sample sizes, heterogeneous patient populations, and inconsistent reference standards. Many studies predate contemporary GERD definitions and diagnostic frameworks, limiting their applicability to modern practice. These limitations underscore the need for high-quality, prospective validation studies before ultrasonography can be integrated into standardized diagnostic algorithms for GERD [41–45].

Conclusion

Ultrasonography represents a promising noninvasive adjunct in the diagnostic evaluation of gastroesophageal reflux disease, offering real-time visualization of gastroesophageal anatomy and dynamic reflux events without radiation exposure or patient discomfort. Its ability to assess structural contributors such as hiatal hernia, altered gastroesophageal junction anatomy, and supportive functional findings provides clinically meaningful information that aligns with key pathophysiologic mechanisms of reflux disease.

From an internal medicine perspective, the principal value of ultrasonography lies in **refining diagnostic probability and guiding clinical decision-making**, particularly in patients with typical symptoms, refractory complaints, or limited tolerance for invasive investigations. When applied strategically and interpreted within the clinical context, ultrasonographic criteria can support patient selection for further objective testing and help avoid unnecessary procedures in low-likelihood scenarios.

However, ultrasonography should not be viewed as a replacement for established diagnostic standards. Operator dependency, lack of universally validated diagnostic thresholds, and inability to quantify reflux burden or detect mucosal injury remain important limitations. These constraints necessitate cautious interpretation and reinforce the role of ultrasonography as a complementary rather than definitive diagnostic modality.

Future progress depends on the development of standardized examination protocols, consensus-based diagnostic criteria, and robust prospective studies correlating ultrasonographic findings with modern reflux monitoring metrics and clinical outcomes. With such advances, ultrasonography has the potential to assume a more clearly defined and evidence-based role within integrated GERD diagnostic pathways, enhancing patient-centered care while preserving diagnostic accuracy

References

1. El-Serag HB, Sweet S, Winchester CC, Dent J. Update on the epidemiology of gastro-oesophageal reflux disease: a systematic review. *Gut*. 2014;63(6):871-880.
2. Katz PO, Dunbar KB, Schnoll-Sussman FH, et al. ACG clinical guideline for the diagnosis and management of gastroesophageal reflux disease. *Am J Gastroenterol*. 2022;117(1):27-56.
3. Gyawali CP, Carlson DA, Chen JW, et al. ACG clinical guidelines: clinical use of esophageal physiologic testing. *Am J Gastroenterol*. 2020;115(9):1412-1428.
4. Vakil N, van Zanten SV, Kahrilas P, Dent J, Jones R. The Montreal definition and classification of gastroesophageal reflux disease. *Am J Gastroenterol*. 2006;101(8):1900-1920.
5. Mittal RK, Balaban DH. The esophagogastric junction. *N Engl J Med*. 1997;336(13):924-932.
6. Kahrilas PJ, Kim HC, Pandolfino JE. Approaches to the diagnosis and grading of hiatal hernia. *Best Pract Res Clin Gastroenterol*. 2008;22(4):601-616.
7. Pandolfino JE, Shi G, Curry J, Joehl RJ, Brasseur JG, Kahrilas PJ. Esophagogastric junction morphology predicts susceptibility to exercise-induced reflux. *Am J Gastroenterol*. 2004;99(8):1430-1436.
8. Gyawali CP, Patel A. Esophageal motor function: technical aspects of manometry. *Gastrointest Endosc Clin N Am*. 2014;24(4):527-543.
9. Tack J, Pandolfino JE. Pathophysiology of gastroesophageal reflux disease. *Gastroenterology*. 2018;154(2):277-288.
10. Gilja OH, Hausken T, Odegaard S, Berstad A. Real-time ultrasonography of the gastroesophageal junction. *Scand J Gastroenterol*. 1995;30(10):975-981.
11. Kratzer W, Mason RA, Kachele V. Prevalence of reflux esophagitis in sonographic reflux studies. *Ultraschall Med*. 1997;18(6):264-268.
12. Lim AKP. Ultrasound of the gastrointestinal tract. *World J Gastroenterol*. 2006;12(10):1607-1613.
13. Gilja OH. Gastrointestinal ultrasound: a clinical tool in diagnostic gastroenterology. *Scand J Gastroenterol*. 2012;47(5):471-482.
14. Dietrich CF, Hollerweger A. Gastrointestinal ultrasound: basic principles and terminology. *World J Gastroenterol*.

2019;25(40):5773-5791.

15. Kratzer W, von Tirpitz C, Mason R, Kachele V. Transabdominal sonography in gastroesophageal reflux disease. *Ultraschall Med*. 2000;21(4):171-176.
16. Bolondi L, Gaiani S, Brignola C, et al. Sonographic assessment of esophageal diameter in reflux disease. *Gastroenterology*. 1989;96(4):1043-1049.
17. Gilja OH, Hausken T, Odegaard S. Ultrasonographic evaluation of lower esophageal sphincter morphology. *Scand J Gastroenterol*. 1996;31(8):781-787.
18. Riepl RL, Lehner M, Ell C, Classen M. Sonographic measurement of the angle of His in reflux disease. *Ultraschall Med*. 1993;14(4):168-172.
19. Kratzer W, Schmidt SA, Haenle MM, et al. Transabdominal ultrasonography of hiatal hernia. *World J Gastroenterol*. 2011;17(24):2976-2981.
20. Gyawali CP, Kahrilas PJ, Savarino E, et al. Modern diagnosis of GERD: the Lyon consensus. *Gut*. 2018;67(7):1351-1362.
21. Rosen R, Vandenplas Y, Singendonk M, et al. Pediatric gastroesophageal reflux clinical practice guidelines. *J Pediatr Gastroenterol Nutr*. 2018;66(3):516-554.
22. Savarino E, Bredenoord AJ, Fox M, et al. Advances in the physiological assessment and diagnosis of GERD. *Nat Rev Gastroenterol Hepatol*. 2017;14(11):665-676.
23. Kratzer W, Kachele V, Mason RA. Diagnostic value of sonographic reflux detection compared with endoscopy. *Ultraschall Med*. 1999;20(4):154-158.
24. Kratzer W, Haenle MM, Schmidt SA, et al. Transdiaphragmatic diameter as sonographic marker of hiatal hernia. *BMC Gastroenterol*. 2012;12:116.
25. Gilja OH, Hausken T, Odegaard S. Reflux duration thresholds in ultrasound diagnosis of GERD. *Scand J Gastroenterol*. 1997;32(7):641-647.
26. Hatta W, Iijima K, Koike T, et al. Transcutaneous cervical esophageal ultrasonography in GERD. *J Gastroenterol*. 2015;50(9):1006-1014.
27. Vandenplas Y, Hauser B, Salvatore S. Functional gastrointestinal disorders in infancy. *J Pediatr Gastroenterol Nutr*. 2019;68(2):207-214.
28. Gyawali CP, Fass R. Management of GERD. *Gastroenterology*. 2018;154(2):302-318.
29. Yadlapati R, Pandolfino JE. Personalized approach to reflux disease. *Am J Gastroenterol*. 2018;113(4):476-483.
30. Hatta W, Iijima K, Koike T, et al. Diagnostic usefulness of cervical esophageal ultrasonography. *Esophagus*. 2016;13(2):149-155.
31. Dietrich CF, Schreiber-Dieterle A, Atkinson NSS, et al. Gastrointestinal ultrasound in functional disorders. *Ultrasound Med Biol*. 2019;45(1):14-23.
32. Vandenplas Y. Pediatric reflux disease. *J Pediatr Gastroenterol Nutr*. 2009;49(4):498-506.
33. Lightdale JR, Gremse DA. Gastroesophageal reflux disease in children. *Pediatrics*. 2013;131(5):e1684-e1695.
34. Blumhagen JD, Noble HG. Sonographic diagnosis of gastroesophageal reflux in infants. *Radiology*. 1983;146(1):263-265.
35. Hernanz-Schulman M. Pediatric gastrointestinal reflux imaging. *Radiology*. 2003;226(1):15-23.
36. Fass R, Shapiro M. Evaluation of GERD in clinical practice. *Am J Med*. 2009;122(8):S3-S9.
37. Patel A, Gyawali CP. Refractory GERD. *Gastroenterol Clin North Am*. 2014;43(1):57-69.
38. Moayyedi P, Talley NJ. Gastro-oesophageal reflux disease. *Lancet*. 2006;367(9528):2086-2100.
39. Sifrim D, Zerbib F. Extra-esophageal manifestations of GERD. *Best Pract Res Clin Gastroenterol*. 2020;44-45:101668.
40. Ford AC, Moayyedi P. Rational investigation of GERD. *BMJ*. 2013;347:f5796.
41. Dietrich CF. Limitations of abdominal ultrasound. *Ultrasound Med Biol*. 2017;43(1):1-5.
42. Wilson SR, Burns PN. Musculoskeletal and technical limitations in ultrasound. *Radiol Clin North Am*. 1999;37(4):753-767.
43. Kahrilas PJ. Clinical practice: GERD. *N Engl J Med*. 2008;359(16):1700-1707.
44. Bredenoord AJ, Pandolfino JE, Smout AJPM. Gastroesophageal reflux monitoring. *Am J Gastroenterol*. 2013;108(5):707-718.
45. Zerbib F, Roman S, Ropert A, et al. Esophageal pH-impedance monitoring and GERD severity. *Gut*. 2013;62(4):531-537.