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Ingestion of Acidic Foods Mimics Gastroesophageal Reflux During pH Monitoring

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Ingestion of acidic foods may produce artifactual drops in pH to <4 that may be difficult to differentiate from a true acid reflux event. We aimed to evaluate intraesophageal pH changes during the ingestion of acidic food and describe the frequency and implications of acidic food ingestion on ambulatory pH monitoring. Ten normal volunteers (six females; mean age, 34) underwent combined impedance–pH testing with a pH electrode placed 5 cm above the lower esophageal sphincter. Each volunteer received 50 ml each of acidic foods in random order. Nadir and mean pH for 30 sec after ingestion of each substance were recorded. Subsequently 100 randomly selected reflux monitor diaries were reviewed, searching for ingestion of acidic foods, and 100 pH tracings were reviewed to evaluate the impact of including/excluding meal periods on percentage time pH <4 and DeMeester scores. All foods produced abrupt drops to pH <4, in 80% of cases exceeding 30 sec. During ambulatory pH monitoring 78% of patients recorded ingestion of at least 1 of the 10 tested substances during meals, the majority admitting ingesting carbonated beverages. Not excluding meal periods would have led to the misinterpretation of 6–16% of tracings, depending on the criteria used to identify abnormal acid exposure. We conclude that ingestion of acidic foods is frequent and carries the risk of overdiagnosing GERD. Current findings support the recommendations to carefully instruct patients to record all oral intake and to exclude meal periods from the analysis.

KEY WORDS: gastroesophageal reflux disease; acidic food; pH monitoring.

During ambulatory pH monitoring, gastroesophageal reflux is traditionally identified by an abrupt decrease in intraesophageal pH to a level <4.0. Commonly ingested substances having a pH <4 include coffee, tea, ketchup, strawberry juice, apple juice, carbonated beverage, wine, lemonade, and orange juice. These acidic substances would be expected to produce a transient decrease in intraesophageal pH during their passage down the esophagus. To avoid recording ingested food as reflux, the actual mealtime is routinely excluded from the 24-hr pH analysis in our laboratory (1). The patient is asked to write in the diary and use the recorder's meal indicator to identify the start and end of the actual eating period. This allows the clinician to then exclude the mealtime from the analysis.

There are, however, limited data on the actual pH produced by the ingestion of acidic foods. It was the purpose of our study to demonstrate that many common foods induce a drop in pH to <4 during movement down the esophagus that mimics gastroesophageal reflux and to identify how frequently these foods are ingested during pH monitoring.

DESIGN AND METHODS

Initially, the U.S. Food and Drug Administration Center for Food Safety and Applied Nutrition was contacted for information regarding the approximate pH of different foods and food products. From the approximate ranges of pH values, 10 known acidic substances (defined as having a pH <4) were chosen:

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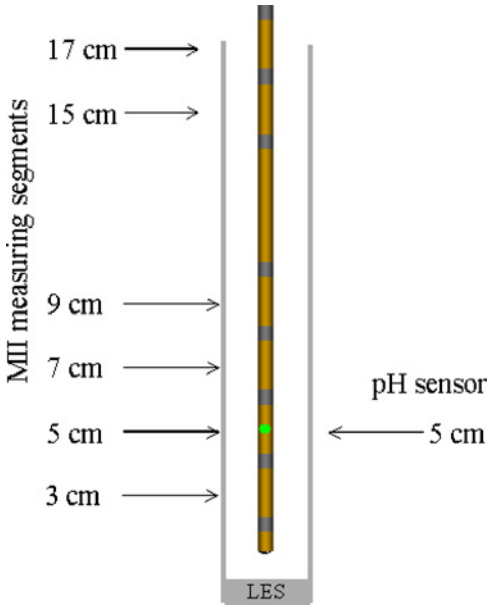

Fig 1. Combined MII–pH catheter. Both the impedance measuring segments and the pH sensor are mounted on the same 2.1-mm catheter. Distances above the lower esophageal sphincter (LES) are shown.

carbonated beverage, coffee, tea, ketchup, orange juice, apple juice, lemonade, red wine, white wine, and strawberry juice. The study in normal volunteers was performed at the Esophageal Laboratory at the Medical University of South Carolina. Healthy volunteers were included in the study if they were 21 years of age and older, were not pregnant or nursing, and did not have active gastrointestinal, cardiovascular, respiratory, or cerebrovascular disease. Each volunteer provided informed consent and the protocol was approved by the Institutional Review Board of the Medical University of South Carolina.

Combined Multichannel Intraluminal Impedance (MII) and pH Testing. Combined MII–pH catheters with an external diameter of 2.1 mm were used for the current study. The antimony pH electrodes were calibrated prior to the study using buffered solutions of pH 4 and pH 7 as recommended by the manufacturer. The combined MII–pH probe was placed with the pH electrode 5 cm above the manometric identified proximal border of the lower esophageal sphincter (LES), and impedance segments were located at 3, 5, 7, 9, 15, and 17 cm above the LES (Figure 1). The combined MII–pH catheter was connected to a stationary setup (InSight Acquisition, Sandhill Scientific Inc., Highlands Ranch, CO) and data from six impedance channels and one pH channel were recorded continuously at a sampling rate of 50 Hz and displayed in real-time mode. Each volunteer, in the upright position, received 50 ml each of carbonated beverage, coffee, tea, ketchup, orange juice, apple juice, lemonade, red wine, white wine, and strawberry juice in random sequence. A 2-min interval was allowed between the ingestion of individual substances. If the pH did not recover to >4 after 90 sec, 50 ml of distilled water was given as a washout (Figure 2). Each substance was ingested after the pH had recovered to >4. For each substance, the nadir pH and mean pH for the first 30 sec after ingestion were calculated. Grouped data for all 10 subjects are presented as median values.

In the second phase of the study, randomly selected diaries from 100 patients having 24-hr pH studies were reviewed. These included 63 females and 37 males, with a mean age of 54 years. The composition of their meals was identified and recorded as reported by the patients. A retrospective review of 100 ambulatory pH tracings was analyzed with and without meals included. The acid exposure time in the proximal (normal values: total, <1%; upright, <1.3%; recumbent, 0) and distal

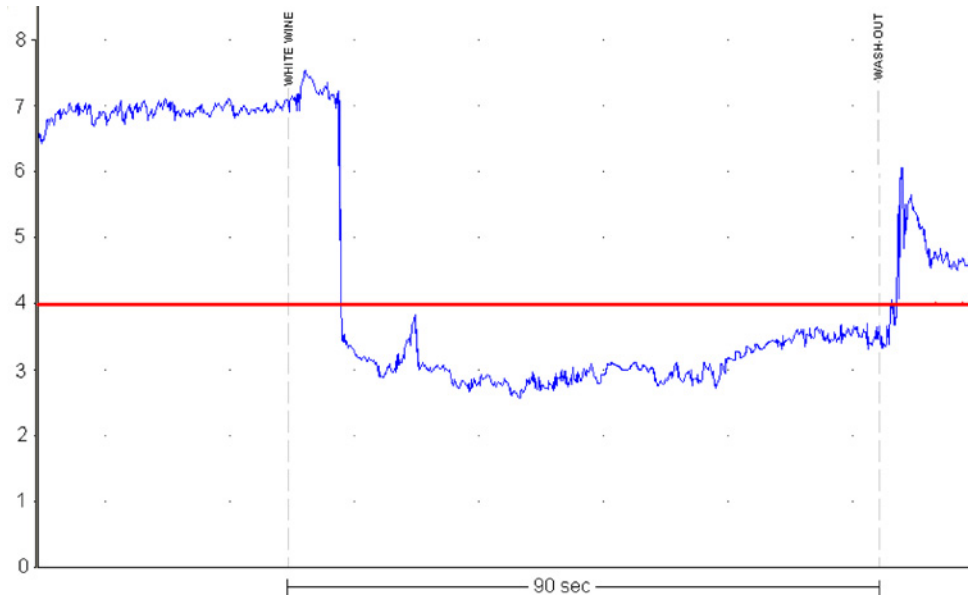

Fig 2. Esophageal pH tracing during ingestion of white wine with slow recovery of pH. After 90 sec a 50-ml water clearance bolus was given.

TABLE 1. NADIR AND 30-SEC MEDIAN PH VALUES PRODUCED BY VARIOUS SUBSTANCES IN 10 HEALTHY VOLUNTEERS AND THE FREQUENCY AT WHICH THESE WERE FOUND IN THE DIARIES OF 100 PATIENTS

	Healthy volunteers (N = 10)		*Frequency of acid food ingestion (N = 100)*
	Nadir pH	*Median 30-sec pH*	
Carbonated beverage	1.9	2.5	45%
Lemonade	2	3.3	14%
Strawberry juice	2.3	3.6	2%
White wine	2.6	2.9	26%*
Red wine	2.8	3.5	
Ketchup	2.9	3	12%
Apple juice	3.1	3.1	17%
Orange juice	3.4	3	22%
Coffee	3.8	4.4	32%
Tea	3.9	4.5	29%

*Patients did not distinguish between white and red wine in the diaries.

(normal values: total, <4.2%; upright, <6.3%; recumbent, <1.2%) and composite Demeester scores (normal: <14.7) were calculated with and without meals excluded. The number of patients who actually had a meal that dropped the pH to <4 was also recorded.

RESULTS

Stationary MII–pH Monitoring. Ten normal volunteers, six female and four male, with a mean age of 34 years, completed the study. The intraesophageal pH rapidly dropped to <4 after ingestion of all 10 acidic substances and remained <4 (range, 2.5–4.5) for at least 30 sec for 8 of the 10 substances (Table 1). The median pH nadir ranged from 1.9 to 3.9. Carbonated beverage consistently produced the lowest pH values, with coffee and tea just reaching a pH level <4. An example of a tracing during carbonated beverage ingestion is shown in Figure 3A compared to a tracing during coffee (Figure 3B).

Chart Review. Of the 100 reviewed patient charts, 78 patients had reported ingesting at least 1 of the 10 tested substances during ambulatory pH monitoring. A carbonated beverage was the most frequently ingested (45/78). As patients did not distinguish between red and white wine in the diaries, the frequency of ingestion of just nine acidic substances as noted in the 100 patient diaries are shown in Table 1. Evaluating intraesophageal pH tracings during meal period identified a pH <4 at least once during meal ingestion in 82% of patients.

Based on the analysis of the percentage time esophageal pH <4 (total/upright/recumbent) with meals excluded, we found 48 normal and 52 abnormal studies. Not excluding the meal periods, we found 44 normal and 56 abnormal studies. Considering the analysis with meals excluded the gold standard, analyzing tracings with meals included would have resulted in six false-positive and 2 false-negative interpretations. Using the DeMeester score without excluding the meal periods, we found 54 normal and 46 abnormal studies. Again, considering the interpretation based on percentage time pH <4 the "gold standard," interpreting the studies based only on the DeMeester score with meals included would have led to 5 false-positive and 11 false-negative interpretations (Table 2). On the other hand, using the DeMeester score after excluding meal periods from the analysis as the gold standard for interpretation, not excluding the meal periods would have led to a discordant interpretation in 6% of instances (four false positives and two false negatives).

DISCUSSION

The current study indicates that during the ingestion of acidic foods, intraesophageal pH declines and remains <4

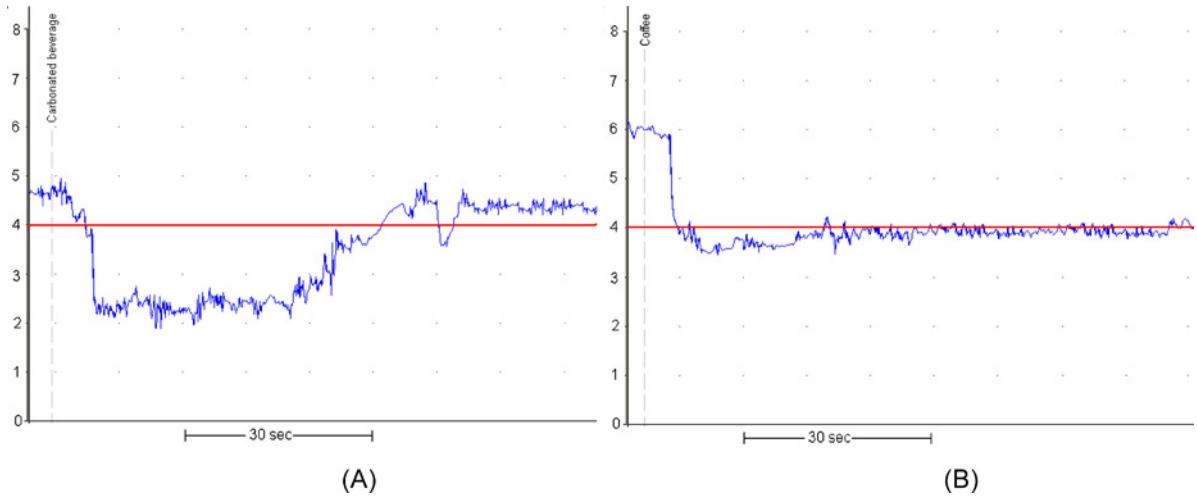

Fig 3. Changes in intraesophageal pH during ingestion of carbonated beverage (A) and coffee (B).

TABLE 2. SENSITIVITY AND SPECIFICITY CALCULATED WITH NO MEAL EXCLUSION

	Sensitivity	*Specificity*	*Discordant diagnoses*
% time esophageal pH <4, no meal exclusion	89%	95%	8%
DeMeester score, no meal exclusion	89%	79%	16%

for an important period of time. Many patients document ingesting these acidic foods during pH monitoring, and including meal periods caries the risk of overdiagnosing GERD in some patients.

Many clinicians regard ambulatory 24-hr pH monitoring as the "gold standard" for diagnosing GERD (2–4). An important aspect of interpretation of 24-hr pH studies is the identification of artifactual decreases in esophageal pH and separation of these from true reflux episodes. A common type of reflux artifact may be seen during ingestion of acidic foods that may produce a false-positive result when analyzing 24-hr pH studies. This was identified by studies in our laboratory that led to the recommendation that meal periods should be excluded from the analysis (1). Exclusion of the actual eating period form the overall analysis eliminates the artifact introduced by meal constituents having pH below 4.0 and has been shown to improve the separation between studies showing normal and abnormal total times for which the pH is <4 (5). One could argue that excluding meals decreases the time of recording and this may influence the interpretation of distal esophageal acid exposure. Using the percentage time pH <4 rather than the actual time pH <4 reduces the influence of study duration in the evaluation of distal esophageal acid exposure. Previous studies have reported a good correlation of percentage time pH <4 during 16- and 24-hr esophageal monitoring (6), suggesting that the reduction determined by meal exclusion should not affect the interpretation of distal esophageal acid exposure.

In the analysis of esophageal pH recordings, pH decreases to <4 are considered indicative of acid gastroesophageal reflux (7, 8). In the present study, all 10 of the group of commonly ingested substances had a median nadir pH <4, and 8 of the 10 substances had a median nadir pH <4 persisting longer than 30 sec after ingestion.

Our results are in contradiction to data reported by Shoenut *et al.* (9), who reported differences that were not significant in the percentage of time pH <4.0 during the ingestion of acidic substances such as cola, juice, and beer. The findings of our study suggest that acidic foods are frequently ingested and may change the interpretation of pH monitoring in 6–16% of patients. Data collected in the current study does not allow us to evaluate the clinical impact of these changes. Specifically designed studies are likely warranted to answer this question.

In addition, analysis of pH monitoring diaries indicated that 78% of patients had ingested at least 1 of the 10 acidic substances during a 24-hr ambulatory pH study, demonstrating that these substances are commonly ingested and have the potential to produce a major artifact. Since the decrease in pH is rapid, it is difficult to distinguish ingestion of acidic foods from true gastroesophageal reflux episodes when patients are not accurately recording every ingested food. It has been recommended that acidic foods and drinks be avoided and diet be standardized (10), but dietary restrictions on ambulatory monitoring may eliminate foods that typically induce the patient's reflux and symptoms (2, 11). In addition, restriction of these and other acidic substances between meal periods would perhaps change the "real life" scenario of the test.

In summary, the results of our study indicate that acid foods are commonly ingested and are likely to produce an artifact that mimics reflux during pH monitoring. These findings support the recommendation that meal times should be excluded from the analysis of pH studies and emphasize that patients be strongly encouraged to record ingestion of every substance in their diary, particularly carbonated beverages ingested during or between meals.

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