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How to Interpret Esophageal Impedance pH Monitoring

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Esophageal impedance pH monitoring provides quantitative data on esophageal acid exposure and has the ability to correlate the symptoms with acid exposure events. The nomenclature for the reflux patterns detected in impedance pH monitoring as well as the normal values have been determined. Data interpretation is similar to 24-hour pH monitoring, ie, searching for an increase in the number of reflux episodes, prolonged acid or volume exposure or increased numbers of proximal reflux events. In particular, the key clinical measurements for impedance testing on proton pump inhibitor therapy are the number of acid and non-acid reflux episodes and their relationship with the symptoms using the symptom index or symptom-association probability.

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Key Words
Gastroesophageal reflux, Electric impedance, Reference values

Introduction

Esophageal impedance monitoring is considered the most sensitive tool for assessing all types of gastroesophageal reflux (acidic, weakly acidic and weakly alkaline), their composition, proximal extent, duration and clearing. Proper and coherent interpretation is needed to apply the results of impedance pH monitoring.

What Is Impedance?

Impedance techniques are based on measurements of the electrical impedance between closely arranged electrodes mounted on a thin intraluminal probe. Pairs of electrodes representing an impedance segment are connected to an impedance voltage transducer, which delivers a measuring current. The output of the measurement represents the electrical impedance around the catheter in the section between the pair of electrodes. The impedance is inversely proportional to the electrical conductivity of the luminal contents and the cross-sectional area between the 2 electrodes. Air has low conductivity and causes an increase in impedance, whereas swallowed or refluxed material has a high conductivity and causes a decrease in impedance.

The changes in the temporal-spatial patterns in impedance have been identified at various levels within the esophagus, allowing differentiation between antegrade (ie, swallow) and retrograde (ie, reflux) bolus movement. In this manner, the im-

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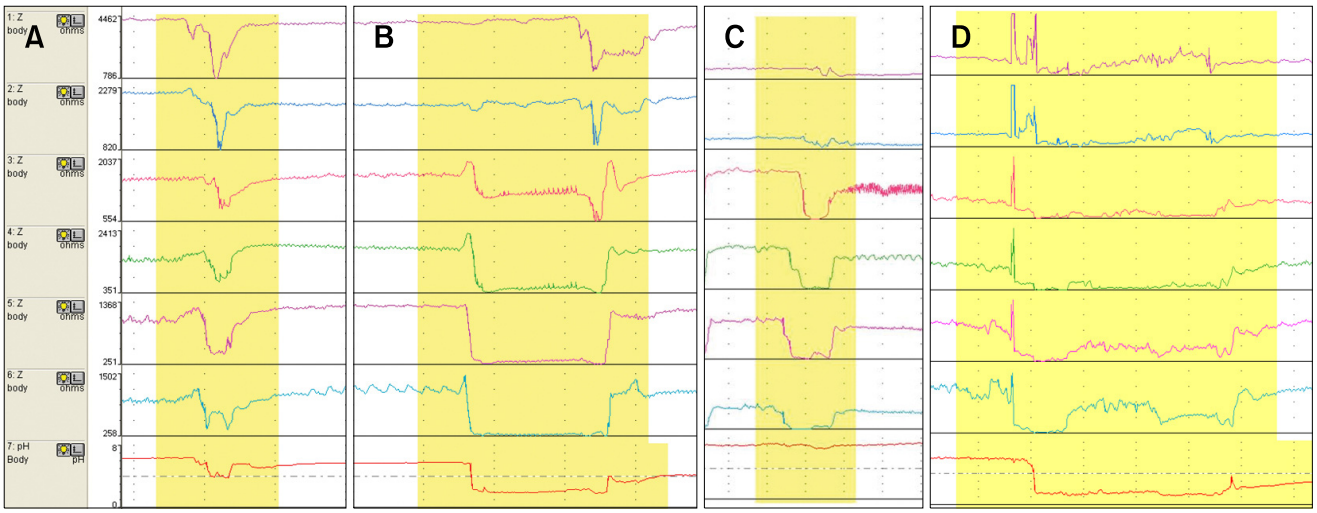

Figure 1. Esophageal impedance pH recordings showing examples of the 4 types of reflux. (A) Weakly acidic reflux, (B) acid reflux, (C) weakly alkaline reflux and (D) superimposed acid reflux.

pedance can be used to evaluate the intraesophageal liquid movements (bolus transit tests and reflux monitoring) or gas movement (aerophagia and belching).

Reflux, Terminology of Impedance pH

A recent consensus report provided a detailed nomenclature for the reflux patterns detected by impedance-pH monitoring.[1] Reflux is defined as either pure liquid or a mixture of liquid and gas detected by impedance. Liquid only reflux is defined as a retrograde 50% decrease in impedance from the baseline in the 2 distal impedance sites. Gas reflux was defined as a simultaneous increase in impedance > 3,000 Ω in any 2 consecutive impedance sites with 1 site having an absolute value > 7,000 Ω. Mixed liquid gas reflux is defined as gas reflux occurring during or immediately before liquid reflux.

The 4 subcategories of reflux are based on the esophageal pH detected by impedance during reflux (Fig. 1): (1) acid reflux, a decrease in pH to < 4; (2) superimposed acid reflux (acid re-reflux), reflux while the pH is < 4 during an acid clearing interval (before the esophageal pH has recovered to > 4 after acid reflux); (3) weakly acid reflux, the pH nadir is > 4 but < 7 during reflux and (4) weakly alkaline reflux, pH remains > 7 or increases to > 7. pH-only reflux is defined as a decrease in pH to < 4 in the absence of reflux detected by impedance monitoring[2,3] and is quite rare.[4]

Acid exposure (%) is defined as the total time the pH is < 4 divided by the time monitored. Bolus exposure (%) is defined as

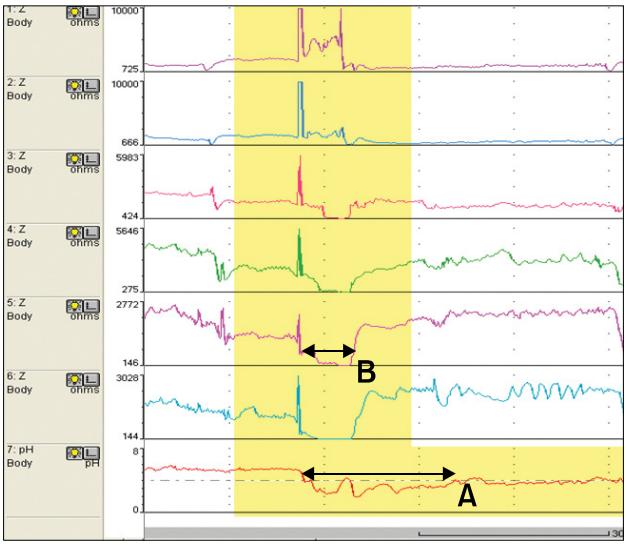

Figure 2. Example of acid reflux. (A) Acid duration measured 5 cm above the lower esophageal sphincter. (B) Bolus duration measured 5 cm above the lower esophageal sphincter.

being analogous to acid exposure by adding the duration of all four reflux subcategories defined by the impedance, and dividing this value by the time monitored. A healthy volunteer study performed by Shay et al[4] revealed the median total acid exposure measured by pH to be 2.4 times higher than that of the total bolus exposure measured by impedance.

The acid duration is defined as the time after acid reflux or a pH only reflux until pH 4 is again achieved for 5 or more

seconds. The bolus duration is the time from liquid bolus entry to liquid bolus clearance, which is defined as the time when the impedance increases to a value denoting liquid reflux entry for > 5 seconds. The bolus duration is measured at the impedance site 5 cm above the lower esophageal sphincter. The bolus duration and acid duration could be compared most accurately by examining the individual episodes of acid reflux that have no superimposed acid reflux (Fig. 2).

Normal Values

If the primary aim of the study is to confirm an unclear diagnosis of gastroesophageal reflux disease, refractory patients with troubling gastroesophageal reflux disease complaints or extraesophageal symptoms or before antireflux surgery should undergo pH testing off medications, and the results would be interpreted based on the traditional acid parameters. For those with well-defined GERD and troubling symptoms that persist on treatment, impedance-pH testing while on therapy would be indicated.[5] In this setting, impedance pH monitoring can help assess the efficacy of proton pump inhibitors (PPIs) and the role of nonacid or acid reflux in persistent symptoms.

Normal values for impedance-pH monitoring off acid-suppression therapy have been determined from US and European studies (Table 1).[4,6] In healthy adults, the total number of reflux episodes measured by impedance-pH was approximately 40 over a 24-hour period. Acid reflux was 2 times more common than weakly acid reflux. Superimposed acid reflux and weakly alkaline reflux were rare. A median of 34% of the upright reflux reached the proximal esophagus. Based on the 95th percentile as the upper limit of normal, they proposed normal total distal reflux to be total reflux events ≤ 73, acid reflux events ≤ 55, weakly acid reflux events ≤ 26 and weakly alkaline reflux ≤ 1.

Acid neutralization to pH 4 takes twice as long as the volume clearance measured by impedance (Table 2). This suggests that although impedance monitoring can determine the clearing of most acid boluses, the pH probe detects even small acid resides.[4,6] Non-acidic reflux (although most is actually weak acid) commonly occurs postprandially when the gastric content is buffered after a meal or during acid suppression with PPIs.[7]

The on-therapy normal values are needed because esophageal impedance pH monitoring is most likely to be used for symptomatic patients on acid-suppression therapy. Vela et al[8] reported that PPI therapy reduced the number of acid reflux episodes with a proportional increase in nonacid reflux, the net result of which was an unchanged total number of reflux episodes on or off therapy as observed during post-prandial studies. The normal range of reflux episodes "on therapy" (< 73) has been determined by extrapolating the data from healthy volunteers "off therapy"[4] and by assuming that PPI primarily changes the pH of the refluxate without affecting the total number of reflux episodes.[8] However, Tutuian et al[9] reported that PPI therapy reduces the number of acid reflux episodes but not the number of non-acid reflux episodes, indicating that the upper limit of normal for patients on twice daily PPI therapy should be 48 reflux events.

Analysis of Impedance pH Data

Evaluation of the data derived from esophageal impedance pH monitoring can be subdivided into analysis of

- the pH data alone,

Table 2. Normal Values for Impedance pH monitoring; Bolus Exposure and Acid Exposure (95th percentile)[4]

	% bolus exposure (Impedance parameter)	% acid exposure (pH parameter)
Total	1.4	6.3
Upright	2.1	9.7
Recumbent	0.7	2.1

Table 1. Normal Values for Impedance pH Monitoring; Reflux Episodes (95th percentile)[4]

	Distal reflux events (5 cm above LES)					Proximal reflux events (15 cm above LES)				
	Total	Acid	Weakly acid	Weakly alkaline	Super-imposed acid	Total	Acid	Weakly acid	Weakly alkaline	Super-imposed acid
Total	73	55	26	1	4	31	28	12	1	2
Upright	67	52	24	1	4	29	25	11	1	2
Recumbent	7	5	4	0	1	3	2	1	0	0

LES, lower esophageal sphincter.

- the impedance (bolus transit) data alone,
- the temporal relationship between pH change and impedance change,
- the temporal relationship between reflux episodes and the occurrence of symptoms

First, impedance-pH monitoring should be analyzed in a quantitative manner, similar to 24-hour pH monitoring, by searching for an increased numbers of reflux episodes, prolonged acid or volume exposure or increased numbers of proximal reflux events. Impedance testing can detect the ingestion of acidic beverages that is characterized by antegrade acidic impedance movement, which may be misinterpreted by traditional pH testing.

The key clinical measurement for impedance testing is the number of acid and non-acid reflux episodes as well as their relationship with the symptoms. In patients on PPI, qualitative analysis of the reflux-symptom association using symptom index or symptom association probability is essential.

Conclusion

Esophageal impedance pH monitoring provides quantitative data on the level of esophageal acid exposure and on the temporal correlation between the patient's symptoms and reflux events. Normal impedance pH values for off PPI therapy have been suggested. In patients on PPI therapy, the primary measurement is the number of acid and non-acid reflux episodes as well as their relationship with the symptoms.

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