EDITORIAL

Improving Esophageal Transit Scintigraphy

ESOPHAGEAL MOTILITY DISORDERS

The esophageal motility disorders that impair swallowing include achalasia, diffuse esophageal spasm, nutcracker esophagus, and nonspecific motor disorders. In addition, systemic diseases like systemic sclerosis and diabetes mellitus have esophageal manifestations. These disorders cause such symptoms as dysphagia, odynophagia, and chest pain that can mimic cardiac pain.

Several methods exist for evaluating patients suspected of esophageal motility disorders. Contrast radiographic studies are of value, especially in excluding structural lesions of the esophagus. An accurate assessment of intraesophageal pressure changes and relationships can be obtained by esophageal manometry. This procedure assesses the amplitude, duration, and velocity of peristaltic contractions; lower esophageal sphincter (LES) pressure and relaxation; and coordinated relaxation of the upper esophageal sphincter (UES). Specific criteria exist to define esophageal motility disorders, and manometry is generally considered the gold standard for their diagnosis. Thus, achalasia is characterized by absent peristalsis in the body of the organ and by increased pressure and incomplete relaxation of the LES; diffuse esophageal spasm by frequent disorderly contractions; nutcracker esophagus by high pressure contractions; and systemic sclerosis by impaired or absent contractions and by decreased LES pressure.

ESOPHAGEAL TRANSIT SCINTIGRAPHY

To evaluate swallowing, one can directly monitor a swallowed radioactive bolus. Kazem introduced this appealing idea nearly 20 yr ago (*1*). The advantages of esophageal transit scintigraphy (ETS) include good patient acceptance, low radiation dose, and the fact that it is quantifiable. The test has been much elaborated over the years (*2*), but as Taillefer et al. (*3*) recently observed, its use "as a clinical diagnostic test has not gained wide acceptance."

As a possibly inevitable consequence of the variety of possible ways that it might be performed, ETS lacks standardization. Technetium-99m-sulfur colloid or dissolved ^{81m}Kr is incorporated into liquid, semi-solid, or solid boluses of various volumes, and monitored with patients upright or supine using anterior or posterior projection. A defined schedule of dry swallows may ensue. Variability extends to the methods of quantitative analysis, which have fallen into two major approaches based on the analysis of time-activity curves for an esophageal region of interest: measurement of the percentage of esophageal emptying after one or more swallows, or the transit time required for esophageal contents to drop below a specified low level. These approaches are roughly equivalent: the patient with an abnormally low percentage of esophageal emptying has an abnormally long transit time. In all, optimizing ETS by comparing all the methodologic possibilities would be a daunting project.

Variations notwithstanding, there is a popular basic clinical method that entails study of the patient in the supine position beginning with the swallowing of ^{99m}Tc-sulfur colloid in 10–20 ml of water. Two laboratories using similar such techniques recently reported contrary conclusions. Assessing whether the esophagus emptied promptly or not, Holloway et al. (*4*) found sensitivities of 100% in achalasia and diffuse esophageal spasm, 75% in nonspecific motor disorders, 43% in nutcracker esophagus, and 0% in hypertensive LES; and a specificity of 86%. They concluded that a role for ETS "as a routine screening procedure is, therefore, yet to be established." Taillefer et al. (*3*) reported the sensitivity of ETS to be 97.3%, 92.3%, and 76.9%, respectively, in patient groups with esophageal motor disorders, gastroesophageal reflux disease, and non-cardiac chest pain. They found an overall sensitivity of 92.1% and a specificity of 87.9%, further asserted that "no clinically significant motor disorders were missed" by ETS, and concluded that it "is a useful noninvasive test for the screening of patients with symptoms thought to be of esophageal origin."

Short of attempting to explain the above discrepancy completely, certain points warrant emphasis regarding the possible shortcomings of ETS. Investigators must guard against treating the esophageal motility disorders as a monolith; the differences in their pathophysiologies could clearly herald differences in the accuracy of ETS. Reported sensitivities of ETS in the controversial entity of nutcracker esophagus have varied from 0% to 94% (*5–8*). The explanation for false-negative cases has been that the high pressure amplitude characteristic of this condition did not impair orderly progression of liquid through the esophagus so long as a peristaltic wave front was present (*7*). In short, the defect of a particular motility disorder may be different from what ETS measures. Other problems of sensitivity are intermittency of the disorder (e.g., diffuse esophageal spasm) and cases at the mild end of a spectrum of severity (e.g., systemic sclerosis). If ETS is too insensitive, it is hard to justify its unconditional use as a screening test for esophageal symptoms. Manometry will be indicated both when ETS is positive, to define

Received Feb. 26, 1991; accepted Feb. 25, 1991.

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the abnormality better, and when it is negative, because of suspicion of a false result.

Conversely, however, some studies have suggested the ability of ETS to detect motility disorders in symptomatic patients with normal manometry. This conclusion is supported by the higher rate of positivity in the patients (16%-100%) than in asymptomatic controls (0%-7%) (*9–12*).

INTRASUBJECT VARIATION

Do normal volunteers always substantially empty the esophagus under the action of a single initial swallow, as reported by some (*5,9,10,12,13*) or sometimes fail to do so, as reported by others (*14–17*)? This is an important controversial question affecting the definition of normal and the determination of specificity. It has appeared to be a question of intra- rather than intersubject variation (*16*): we have inferred that aberrant swallows occur sporadically in normal subjects (*17*). A possible explanation for such events would be deglutitive inhibition, the inhibition of peristalsis when the interval between successive swallows is too short (e.g., less than 10 sec) (*18, 19*). This may be detectable by examination of standard images or condensed dynamic images (CDIs) (Fig. 1) or of time-activity curves, with special attention to proximal regions. We have found aberrant swallows to occur without such tell-tale signs, however, and without the subjects reporting in our standard post-test interview that they had swallowed prematurely. The cause of an aberrant swallow is therefore not always clear. In any case, deglutitive inhibition is a reason to maintain intervals of at least 15 sec in the wet and dry swallow sequences of ETS. Normal subjects' aberrant swallows in ETS have their counterparts in cineesophagography (*20*) and manometry (*21,22*), and the analysis of multiple swallows is routine in manometry. The occasional aberrant swallow in a normal subject is not representative of his or her swallowing ability.

In this issue of the *Journal*, Tatsch et al. (*23*) present findings that confirm significant intrasubject variability of ETS with regard to esophageal emptying in a single swallow, and like Bartlett et al. (*16*), they report this to occur in abnormal as well as normal subjects. This phenomenon can greatly affect the accuracy of conventional methods of ETS that rely on measurements of first-swallow behavior, and a remedy is needed. The possible solutions and their attendant problems need to be considered critically, including the multiple swallow method of Tatsch et al. (*23*). The latter entails six sequential swallows of boluses labeled with ^{99m}Tc-sulfur colloid, with measurement of percentage emptying in 10 sec, applied both to the individual swallows and a computer-generated composite swallow.

This multiple swallow technique engenders a problem of background correction from one swallow to the next. Subtracting the inter-swallow radioactivity in the esophageal region of interest has the shortcoming that residual activity from a preceding swallow can be cleared with the following one and lead to an impossibly high calculated emptying value for an individual swallow (*23*). Alternative treatments of background should be explored. Residual radioactivity represents not just simple background but a residual intraesophageal volume to which the new bolus is added. The analysis should take this into account. An attempt to empty the esophagus more completely between boluses, as by multiple dry swallows in the erect position over a sufficient time interval, could diminish the residual. A multiple swallow test using a short half-life tracer like 13-sec ^{81m}Kr (*19*) or 30-sec ^{195m}Au (*24*) solves the problem of residual activity but sidesteps the problem of residual volume. It furthermore provides for high counts with less radiation burden, but at the loss of the convenience and economy of ^{99m}Tc.

Consideration should be given to the best way to express and use the information about the distribution and average behavior of any individual's multiple swallow results. For example, given a normal subject who emptied the esophagus well in five of six swallows and poorly in one, the arithmetic mean of the quantitative results would not reflect the subject's typical behavior. The median result or the percentage of the six swallows that were effective might serve better.

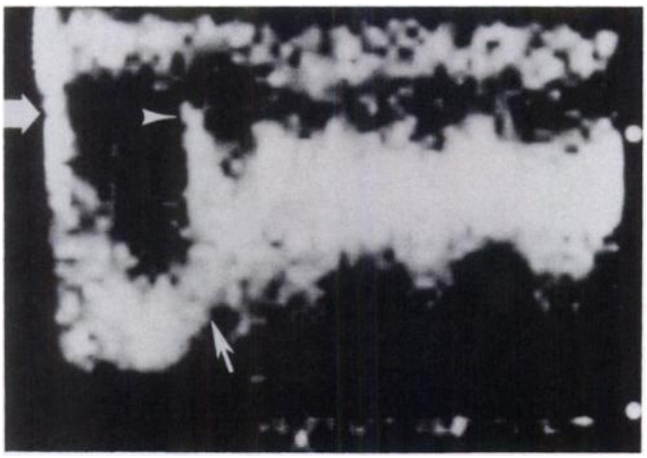

FIGURE 1. Deglutitive inhibition illustrated in a CDI encompassing 24 sec. Dots at the right mark the upper and lower esophageal sphincters. The subject performed the initial swallow of the test bolus on command (thick arrow) but retained some activity in the mouth or oropharynx, making it possible to visualize a premature second swallow (arrow head) initiated 6 sec later. The swallow then in progress was inhibited (thin arrow) leading to retention of activity. Compare with uncomplicated normal downward transit in Figure 6A of Tatsch et al. (*24*) and examples of deglutitive inhibition presented by Ham et al. (*32*).

We have favored the grading of ETS by means of the emptying obtained after four swallows (one wet and three dry) (*2*), because a blunting of the disruptive effect of intrasubject variability is thus achieved. In patients with systemic sclerosis, this parameter correlated better with manometric measurements than did the emptying measured immediately after the initial swallow (unpublished results).

However, useful information may be uniquely present in initial wet swallows. Buthpitiya et al. (*25*) examined the leading edge of the swallowed bolus, measured the rate of its transit to the gastroesophageal junction and associated this measurement with the role of the pharyngeal pump in deglutition. A parameter that we have described, the mean transit time of the rapid component of the initial swallow (*26*) may prove to have a similar significance.

CONDENSED DYNAMIC IMAGES

Because the esophagus is effectively a straight, unidimensional channel, the dynamic transit process there lends itself to depiction by CDIs (*26–29*). Consecutive dynamic image frames are compressed individually by row summation into columns, which are then assembled in order, side by side, to produce these functional images. They are neither a requisite nor a substitute for the generation of the objective diagnostic parameters that derive from esophageal time-activity curves; rather, their value is to facilitate qualitative assessment of intraesophageal events. Tatsch et al. (*23*) disclosed gastroesophageal reflux, retrograde and oscillatory bolus movements, and regional retention of activity by means of CDIs. We have described oscillatory patterns obtained from serial dry swallows (*2,30*). Caution is called for in the diagnostic interpretation of CDI patterns. For example, rhythmic oscillations are not necessarily due to esophageal spasm; they can be a passive response to respiration (*2,30*). Ham et al. (*31*) elegantly demonstrated deglutitive inhibition using CDIs. Figure 1 is an illustration of this phenomenon from our laboratory.

By summing six CDIs that have been aligned according to the starting points of the swallows, Tatsch et al. (*23*) have in effect performed deglutitive gating. This is analogous to the CDIs that Groch et al. (*32*) derived from isolated, narrow, cross-sectional regions of the heart in gated bloodpool studies as an aid in evaluating wall motion. As such, it underlines the parallels between nuclear esophagology and cardiology as to quantitative methodology and functional imaging.

CONCLUSION

The report of Tatsch et al. (*23*) of improved discrimination of esophageal transit scintigraphy by means of a multiple swallow approach that compensates for intrasubject variation represents welcome progress. Their data supporting better discrimination with a semi-solid than a liquid bolus also deserve attention. Refinement of esophageal transit scintigraphy should continue. Sensitivity may be improved by stresses like abdominal compression (*33*), Trendelenburg or prone position (*34*), and edrophonium (*35*) or other drug provocations. We can hope in time to achieve a test with a well-defined role and wide acceptance.

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Erratum

Please note the following corrections for the article, "Combined Technetium Radioisotope Penile Plethysmography and Xenon Washout," by Alan N. Schwartz and Michael M. Graham (*J Nucl Med* 1991; 32:404–410).

In the abstract, the sentence regarding peak corporal rates should read: Peak corporal rates corrected for outflow ($r = 0.88$) and uncorrected for outflow ($r = 0.91$) and change in volume over 2 min centered around peak flow ($r = 0.96$) all correlated with angiography.

In Table 3, PCIF (ml/min) for normals is ≥ 20 *not* ≥ 2.0.

In the reprints contact line, the institution is Stevens Memorial Hospital in Edmonds, WA.