Dynamic Esophageal Scintigraphy

John J. Reilley, Leon S. Malmud, Robert S. Fisher, Gregory Applegate, and Marie-Louise DeVegvar

Temple University Hospital, Philadelphia, Pennsylvania

Esophageal scintigraphy was developed in order to quantitatively evaluate esophageal transit in patients with a variety of esophageal disorders. The study is performed with orally administered technetium-99m sulfur colloid in water, using a gamma camera on-line to a digital computer. Esophageal transit is expressed as the percent emptying for each of the first 15-sec intervals for 10 min after an initial swallow and at 15-sec intervals after serial swallows. Esophageal transit is significantly decreased in patients with motor disorders of the esophagus, compared to normal controls. In patients with reflux esophagitis, esophageal transit was abnormal when the reflux disease was accompanied by abnormal motor function. The technique we describe is the first quantitative test of esophageal function; it is a useful, sensitive, scintigraphic technique for evaluation of esophageal transit.

The techniques currently used to study esophageal motor function include barium cine-esophagography, acid clearance test, and esophageal manometry. Each of these techniques has some significant limitation and none is quantitative. For example, although cine-esophagography is noninvasive, the radiation burden to the patient is not insignificant. The acid clearance test requires intubation with a pH electrode and is at best semiquantitative in addition to being invasive in character. Esophageal manometry records intralumenal pressures, which correlate with esophageal motor activity, but not necessarily with esophageal transit. Until recently, a quantitative technique for evaluating esophageal function was not available. We developed a noninvasive scintigraphic technique to quantitate the rate of esophageal emptying of a liquid bolus as a measure of the rate of esophageal emptying in normal subjects and in patients with a variety of esophageal disorders or symptoms referable to the esophagus (*1*).

Materials and Methods

Initially, 62 patients were studied, including 15 asymptomatic normal volunteers, eight patients with achalasia, ten patients with diffuse esophageal spasm, five patients with scleroderma, and 24 patients with symptomatic gastroesophageal reflux (*1*). Esophageal manometry was used to detect primary motor disorders of the esophagus in this patient population. In additon, gastroesophageal reflux was defined as heartburn in patients with reflux demonstrated by gastroesophageal scintigraphy (*2*). The patients with reflux disease were subdivided based upon the manometric findings into two groups: those with normal esophageal motor function (*3*) and those with nonspecific motor disorders in the body of the esophagus (*4–6*) characterized by an increased number of repetitive and nonprogressive, simultaneous contractions.

Esophageal manometry was performed using a 3 lumen-tube assembly. Intralumenal pressures were transmitted by three water-filled catheters to external transducers. The recording catheters were arranged in order to measure pressures through side orifices, 1.2 mm in diameter, spaced at 5-cm intervals. The recording assembly was introduced into the stomach via the nose, after the patient had fasted overnight. The tube assembly was then withdrawn in 1-cm increments from the stomach through the lower and upper esophageal sphincters and then into the pharynx; recordings were taken at 1-min intervals at each station. Simultaneous respiration and swallowing were measured by belt pneumographs placed around the chest and over the larynx.

Esophageal emptying was measured following an overnight fast. The subject (volunteer or patient) was positioned supine under the gamma camera set at a 140 keV ± 10% window with a diverging collimator. The subject ingested 300 μCi of Tc-99m sulfur colloid diluted in 15 ml of tap water with a sipping straw in a single swallow. The subject was then instructed to swallow on command at 15-sec intervals for 10 min. This must be accomplished without additional fluid intake. Data are stored on magnetic tape or disc and processed later. The computer processing consists of outlining an area of interest over the esophagus for each patient

For reprints contact: John Reilley, Temple University Hospital, Dept. of Nuclear Medicine, 3401 N. Broad St., Philadelphia, PA 19140.

0091-4916/82/1002/71-04$2.00/0

using a light pen (Fig. 1). Sequential count rates within the esophageal area of interest are used in order to determine the rate of esophageal transit. The formula for esophageal transit is:

$$C_t = \frac{E_{max} - E_t}{E_{max}} \times 100,$$

where C_t represents percent esophageal transit at time t; E_{max} represents the maximal count rate in the esophagus, and E_t represents the esophageal count rate at time t. Esophageal emptying is determined by counting the esophageal activity for 15 sec following successive swallows at 15-sec intervals for 10 min. The rate of esophageal emptying after a single wet swallow is determined by counting esophageal activity at 1-sec intervals for 15 sec after the initial swallow.

Results

As noted in Fig. 2, sequential esophageal activity decreases rapidly in normal subjects. At 4–10 sec after the initial swallow, the esophagus is usually not visualized any longer on the oscilloscope of the gamma camera. However, low count rates are still detectable over the esophageal area of interest using the computer. By comparison, symptomatic patients, such as those with achalasia (Fig. 3), fail to clear activity from the esophagus despite repeated swallows at 15-sec intervals for as long as 10 min.

Figure 4 demonstrates that esophageal emptying is diminished significantly throughout the study in patients with achalasia or scleroderma as compared to normal control subjects. For example, after the eighth swallow, greater than 90% of the activity was cleared in normal subjects. By comparison, after the eighth swallow, the emptying rates for patients with scleroderma or achalasia ranged from 15 to 40%. Similarly, after 40 swallows, the esophageal emptying rates in normal volunteers was greater than 90%; it ranged from 20 to 60% in patients with scleroderma or achalasia. Patients with diffuse esophageal spasm represented an intermediate group; their values were neither normal nor clearly as abnormal as the values in patients with scleroderma or achalasia. Esophageal emptying was reduced significantly during the first half of their studies but was normal by the twentieth swallow.

The rates of esophageal emptying during the first 15 sec following the initial swallow of the test bolus are decreased significantly in all groups of patients with primary motor disorders of the esophagus, including those with diffuse esophageal spasm. Thus, the first 15-sec interval could be used to clearly separate normals from all other patient groups. Lastly, patients with

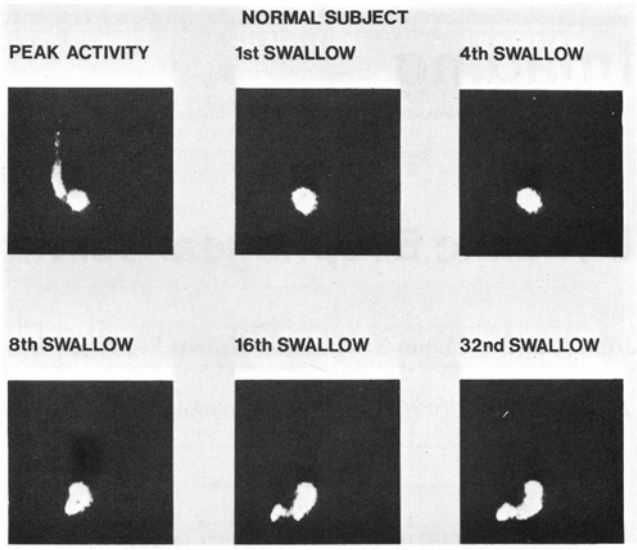

FIG. 2. Serial esophageal scintiscans in normal subject. Esophagus is not visualized by last 1-sec exposure of first swallow.

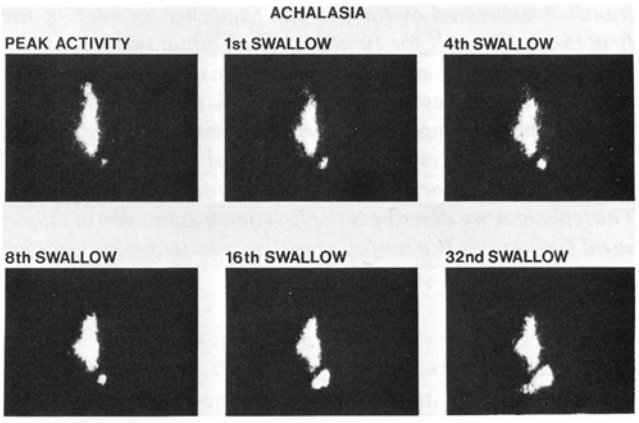

FIG. 3. Serial esophageal scintiscans in patient with classical achalasia. The esophagus does not clear after 40 swallows (10 min).

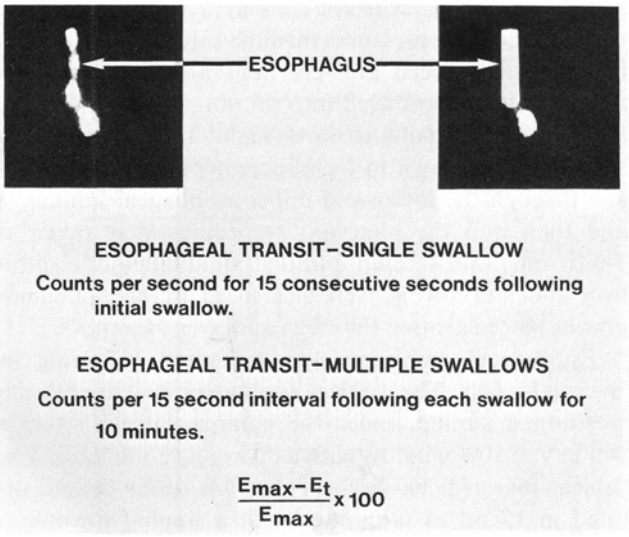

FIG. 1. Esophageal scintiscan and esophageal area-of-interest for quantitating esophageal transit. Formula for calculating esophageal transit after either a single swallow or multiple swallows is shown, where E represents the maximal count rate in the esophagus (immediately after initial swallow) and Et, the esophageal count rate at time t. (Figures 1–5 are reproduced with permission of *Gastroenterology*.)

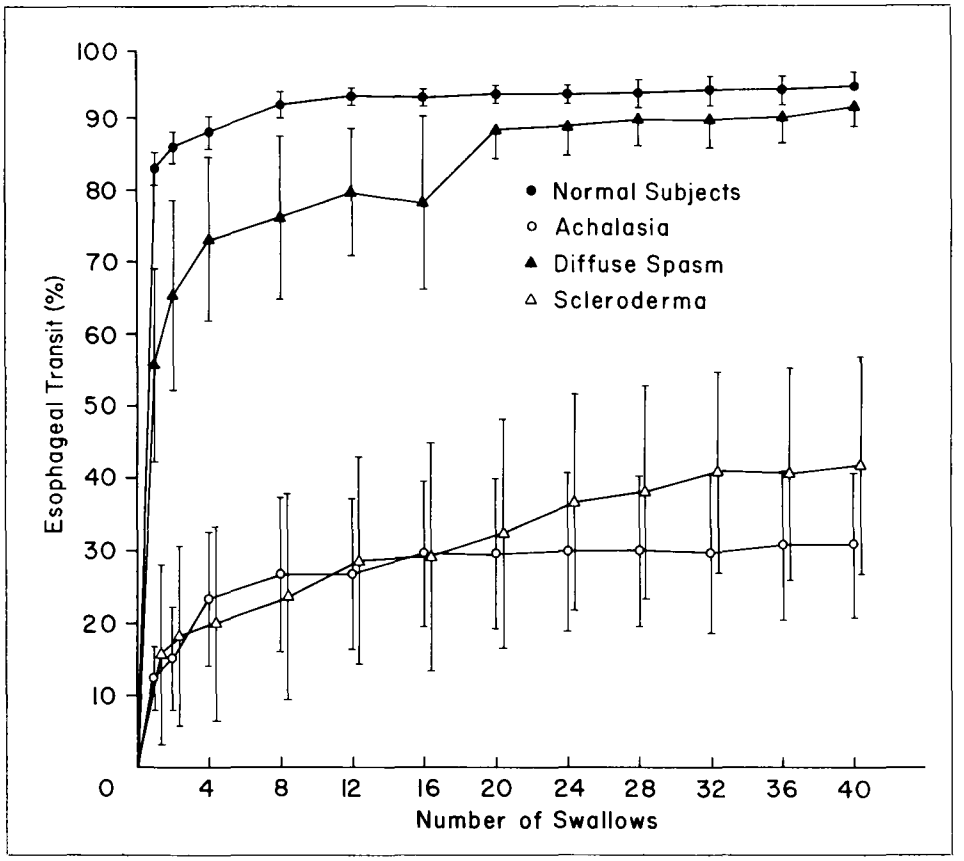

FIG. 4. Esophageal transit after multiple swallows in 15 normal subjects, eight patients with achalasia, ten patients with diffuse esophageal spasm, and five patients with scleroderma. Each point represents the mean ± SEM for esophageal transit. Each swallow represents a 15-sec time interval.

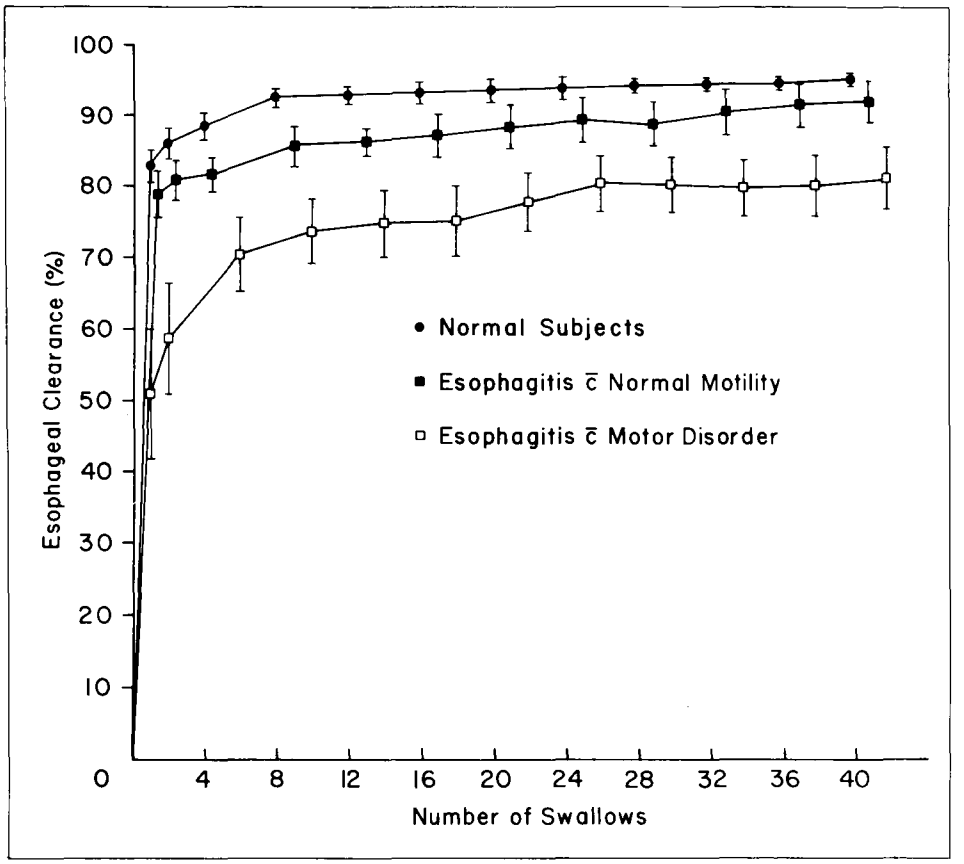

FIG. 5. Esophageal transit after multiple swallows in 15 normal subjects and patients with symptomatic gastroesophageal reflux with and without motor disorder of the esophagus. Each point represents the mean ± SEM for esophageal transit. Each swallow represents a 15-sec time interval.

symptomatic gastroesophageal reflux had diminished esophageal emptying rates after serial swallows (Fig. 5).

Discussion and Conclusions

Esophageal scintigraphy is a rapid, safe, easily performed screening test of esophageal transit and it is an easily quantifiable technique. Abnormal esophageal clearance can be demonstrated in symptomatic patients who have no roentgenographically detectable abnormalities. In addition to better sensitivity, esophageal scintigraphy offers other advantages over barium cineesophagography and acid clearance testing. For example, the radiation burden to the patient from esophageal scintigraphy is a small fraction of that of cineesophagography, which results in approximately 5 rads/min of exposure. Furthermore, no contrast medium is used in the radionuclide technique; thus, the density of barium (specific gravity: 1.5 to 2.0) and its viscosity are not factors in this test.

Another advantage of the radionuclide technique is that it does not require intubation as does acid clearance testing, nor does it use any fragile equipment such as a pH electrode (*3*). Also, in some normal individuals acidification fo the esophagus may affect esophageal motor function, and esophageal scintigraphy does not use an acid medium. Comparative studies could be performed with Tc-99m sulfur colloid in acid or in base if these studies were of physiologic interest.

Specificity of esophageal scintigraphy appears to be high in comparison to roentgenographic techniques. All the patient groups with abnormal esophageal motor function on manometric testing also demonstrated decreased esophageal emptying by scintigraphy. Similarly patients with achalasia or scleroderma had abnormal scintigraphic patterns of esophageal clearance. Patients with diffuse esophageal spasm were also statistically separable from more severe disorders, as well as from normal controls.

As might have been predicted, esophageal transit is decreased in patients who present with symptomatic gastroesophageal reflux. Furthermore, esophageal clearance is more severely impaired in patients with a coexisting, identifiable esophageal motor abnormality shown on manometry than it is in patients with gastroesophageal reflux but no identifiable esophageal motor abnormality shown on manometry. In conclusion, esophageal scintigraphy is a sensitive, quantitative test for evaluating esophageal emptying. Its rapidity, ease of performance, and noninvasive characteristics are already finding wide clinical application and providing the clinician and investigator with useful information about esophageal transit.

References

1. Tolin RD, Malmud LS, Reilley J, et al. Esophageal scintigraphy to quantitate esophageal transit (quantitation of esophageal transit). *Gastroenterology* 1979;76:1402–08.

2. Fisher RS, Malmud LS, Roberts GS, et al. Gastroesophageal (GE) scintiscanning to detect and quantitate GE reflux. *Gastroenterology* 1976;70:301–08.

3. Eastwood GL, Castell DO, Higgs RH. Experimental esophagitis in cats impairs lower esophageal sphincter pressure. *Gastroenterology* 1975;69:146–53.

4. Hookman P, Silbinger MI, Donner MW, et al. Acid induced esophageal motor abnormalities. A cine-manometric study. *Gastroenterology* 1965;48:822.

5. Battle WS, Nyhus LM, Bombeck CT. Gastroesophageal reflux: diagnosis and treatment. *Ann Surg* 1973;177:560–64.

6. Donner MW, Silbinger MI, Hookman P, et al. Acid barium swallows in the radiographic evaluation of clinical esophagitis. *Radiology* 1966;87:220–25.