Effect of Bolus Composition on Esophageal Transit: Concise Communication

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The technique of esophageal scintigraphy was developed as a sensitive, quantitative, noninvasive test of esophageal transit. Esophageal scintigraphy was performed in 40 asymptomatic normal volunteers in order to determine the effect on esophageal transit of the following: body posture (sitting vs. supine), liquid vs. solid, the solid being either a standard #4 gelatin capsule of the size used for antibiotic capsules, or a cube of solid food such as cooked chicken liver. The results showed that liquids emptied completely from the esophagus after one swallow, whether supine or sitting. Capsules or liver cubes, when ingested without water, frequently remained in the esophagus for up to two hours without the subject's having any sensation that the solid had not left the esophagus. Both capsules and liver cubes cleared the esophagus better in the upright than in the supine position. When gelatin capsules were swallowed with as little as 15 ml of water, but after a preliminary sip of water, there was complete transit in each case. The study suggests that the practice of assisting patients into a sitting position and instructing them to take a sip of water before attempting to swallow a capsule will assure better transit of the capsule even when swallowed with as little as 15 ml of water. This may reduce the incidence of esophagitis following oral antibiotics, and of esophageal erosions from aspirin-containing medications.

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Recently, scintigraphic techniques have been introduced for the detection of gastroesophageal reflux and for the measurement of esophageal transit (*1*,*2*). One of the primary advantages of scintigraphy as compared to contrast radiography is that scintigraphy is quantitative. In addition, esophageal scintigraphy is rapid, noninvasive, and results in a low radiation burden to the patient. The objectives of this study were threefold: (a) to determine the influence of body position on esophageal transit; (b) to evaluate the transit of a standard gelatin capsule through the esophagus when administered with or without water; and (c) to compare the rate of transit of a standard gelatin capsule with a piece of solid food, i.e., a one-centimeter cube of radiolabeled chicken liver.

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METHODS

Esophageal scintigraphy was performed on 40 asymptomatic normal subjects positioned supine under the diverging collimator of a gamma camera interfaced on line to a digital computer. The method of measuring esophageal transit uses (a) 15 ml of water mixed with 100 μCi of technetium-99m sulfur colloid as a radioactive marker, or (b) a standard #4 gelatin capsule, of the size used for tetracycline capsules, carrying Whatman #2 filter paper impregnated with 50 μCi of the same radiopharmaceutical, or (c) a 1-cm radioactive liver cube obtained from a chicken that had been injected in vivo with Tc-99m sulfur colloid to provide an intracellular label of its Kupffer cells. Using the method of Meyer et al. (3), the liver was harvested, cooked, and diced into 1-cm cubes containing approximately 100 μCi per cube.

After positioning, subjects were instructed to swallow the water, capsule, or liver cube and then to continue swallowing at 15-sec intervals for 10 min (40 swallows). Esophageal areas of interest were defined with a light pen as described previously (*2*). The time and number of swallows necessary for the radioactivity to clear from the esophagus were recorded for each type of bolus. Following completion of the esophageal transit test for either a capsule or a liver cube, subjects were administered 15 ml of water mixed 50 μCi of Tc-99m sulfur colloid in order to outline the esophagus and stomach. This defined the distal end of the esophagus. To measure the effect of gravity on esophageal transit, studies were performed with the subject supine or sitting. Capsules were ingested both dry and with water. The effect of additional water on esophageal transit of capsules was determined by having the subjects swallow the capsules with 15 ml of water, or following or followed by a 15-ml bolus of water. Ten subjects were included in each study group.

The radiation dose for each transit study with 100 μCi of Tc-99m sulfur colloid is approximately 10 millirads to the whole body and 30 millirads to the upper large intestine, the target organ. This dose contrasts favorably with that from fluoroscopy, which delivers approximately 5000 millirads per minute of exposure time (4). Our protocol was approved by the Human Research Review Committee of Temple University Medical School on June 22, 1977.

RESULTS

A. Supine. Examples of esophageal transit of a water bolus, a capsule, and a liver cube are shown in Fig. 1. Initially, studies were performed in the supine position so that the effect of gravity would be eliminated. Complete transit of a water bolus occurred after one swallow (Table 1). In contrast, liver cubes and capsules passed on infrequently, even in response to multiple swallows (3 cubes of 10 and 2 capsules of 10). If a capsule were to pass into the stomach, it did so after a single swallow. Liver cubes, even when they passed on completely, moved through the esophagus in a stepwise fashion (Fig. 1) requiring multiple swallows to finish the transit (Table 1). Some capsules and liver cubes remained in the esophagus for periods up to 2 hr. In 90% of instances, subjects were unaware that the capsules had not passed into the stomach.

B. Sitting position. With subjects sitting, water emptied after a single swallow. Esophageal transit of both capsules and liver cubes improved with sitting subjects compared with the supine position. Complete

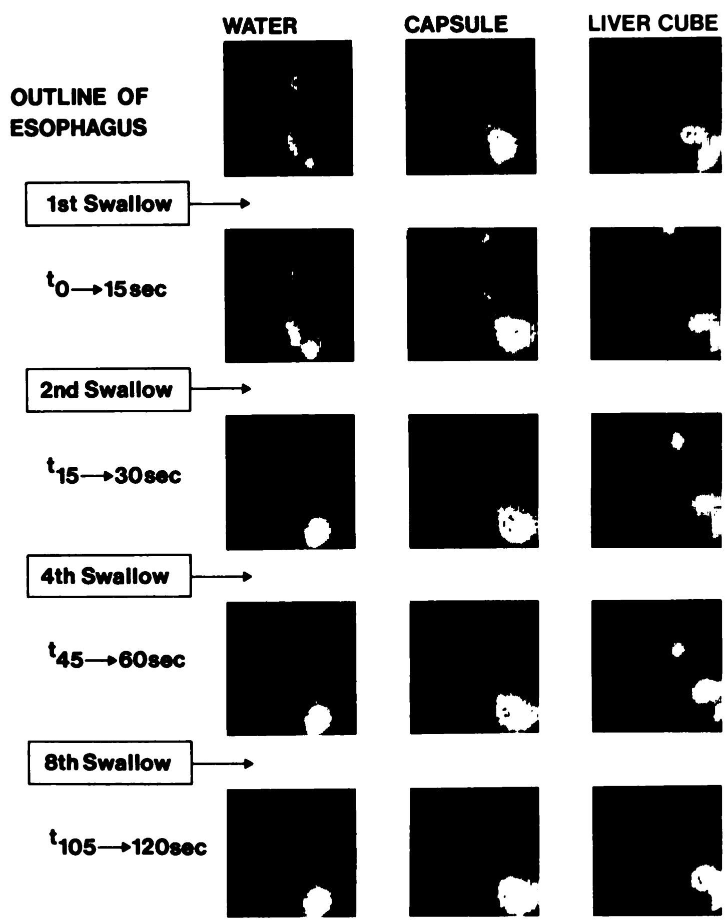

FIG. 1. Esophageal transit of a water bolus, a capsule and a liver cube in supine subjects. Outline of esophagus is shown for each subject in top scan of each column. (Each subsequent row shows images summed over 15 sec). Number of swallows and time in seconds after initial swallow are shown in at left. Both water bolus and capsule emptied almost completely after first swallow, as shown in third row (t, 15–30 sec). Liver cube progressed through esophagus after repetitive swallows, but did not complete transit until eighth swallow.

TABLE 1. COMPLETE PASSAGE THROUGH THE ESOPHAGUS

	Number of swallows							Total emptying
	1	4	8	12	16	20	40	%
Water Bolus								
Supine	10*	10	10	10	10	10	10	100
Sitting	10	10	10	10	10	10	10	100
Liver Cube								
Supine	0	1	2	3	3	3	3	30
Sitting	0	1	4	5	6	6	7	70
Capsule								
Supine	2	2	2	2	2	2	2	20
Sitting	2	2	3	4	4	5	5	50
Supine + H_42O	6	6	6	6	6	6	6	60
Sitting + H_2O	8	8	8	8	8	8	8	80
Sitting								
H_2O before (lubricant)								
H_2O with capsule	8	10	10	10	10	10	10	100
H_2O after (chaser)								

* Numbers represent the number out of 10 subjects who cleared the test bolus after the designated number of swallows.

transit occurred with 5 out of 10 capsules and 7 out of 10 cubes.

C. Addition of water. Capsules swallowed with 15 ml of water, subject sitting, passed on completely in 8 out of 10 cases. If the capsule did not clear from the esophagus within 10 min (40 swallows), an additional 15-ml bolus of water was swallowed, but in both cases, the capsules remained lodged in the esophagus despite the additional water (Fig. 2). In the example shown, the capsule did not transit despite 40 swallows (left). The radiolabeled bolus of water (arrow) moved down from the pharynx, through the esophagus, and into the stomach (right) but did not move the labeled capsule. In contrast, when capsules were swallowed with water, following an initial 15-ml water bolus (lubricant), and then were followed by a third 15-ml water bolus (chaser), complete emptying was observed in all 10 subjects studied in the sitting position.

DISCUSSION

The standard contrast medium for radiographic study of esophageal motor function is barium sulfate suspended in water (*5–8*). Since a major portion of the average diet is in the form of solid food, attempts have been made to assess esophageal transit of solids by loading barium into cylinders of gelatin (*9*), marshmallows (*10,11*), cotton pledgets, tablets (*12,13*), capsules (*14*), and bread. Unfortunately, these techniques are difficult to quantitate and are associated with significant radiation burdens to the study subjects. Booth and others used a pH electrode and a bolus of 0.1 *N* hydrochloric acid to assess esophageal emptying of acid (*15,16*). This acid clearance test has been limited by the need for intubation and placement of a fragile pH electrode, as well as by the restriction to clearance of acid alone. None of the nonscintigraphic methods is able to quantitate esophageal transit.

The results of our study demonstrate that swallowed boluses of varying physical composition move through the esophagus at different rates. Water boluses emptied completely into the stomach after one swallow in both the supine and sitting positions. Capsules and liver cubes, ingested dry, remained in the esophagus in most subjects despite repeated swallows, sometimes for 2 hr, unknown to the subjects. Only moderate improvement in the transit of solids was observed in the sitting position compared with the supine. Ingestion of capsules with water improved their transit, but some failed to move on regardless of body position. Only when the swallowing of capsules was preceded and followed by a 15-ml swallow of water was complete transit observed in all cases. Recently, Kjellen et al. reported an esophageal transit time of 6.6 ± 2.1 (s.d.) seconds for gelatin boluses swallowed with water (*17*). They did not mention incomplete emptying of gelatin boluses in any subjects. Superficially, their results seem to conflict with those reported here, but there were differences in technique. Kjellen used a solid gelatin bolus, not a capsule; he studied subjects in the sitting position; and his gelatin boluses were swallowed with water. The two studies are not really compared.

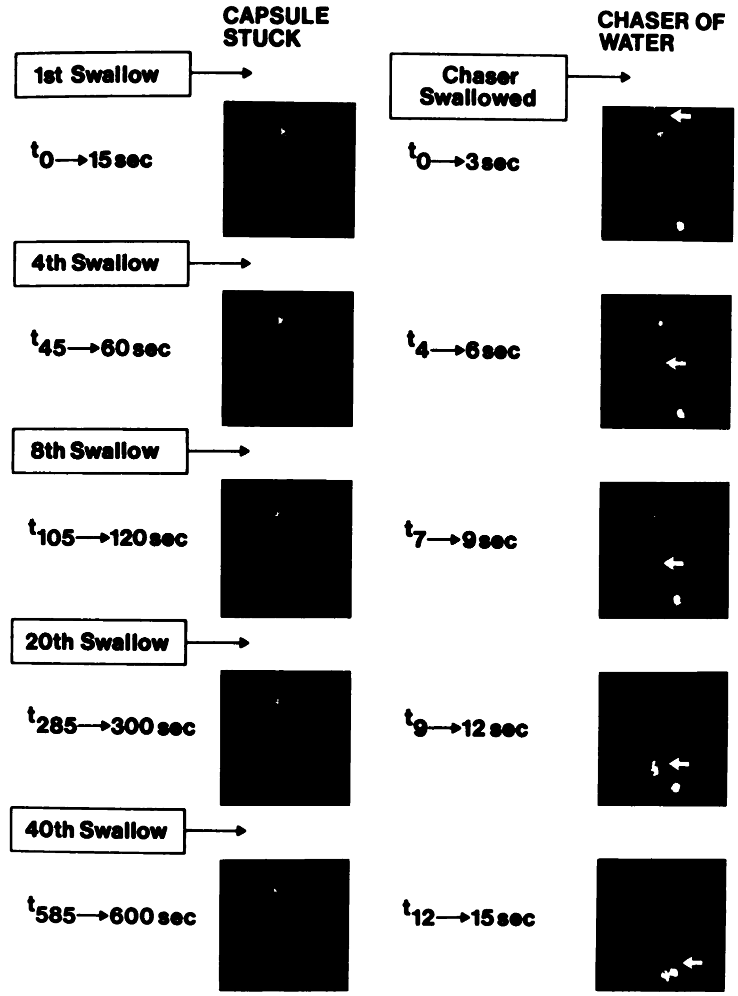

FIG. 2. Serial esophageal scintigraphy in a sitting subject who has swallowed a labeled capsule (left). Number of swallows and time in seconds after initial swallow are shown at left. Labeled capsule failed to pass from esophagus despite 40 swallows (600 sec). After 600 sec, a 15-ml bolus of water labeled with Tc-99m sulfur colloid was swallowed (right). Time in seconds after water bolus was swallowed is shown. Water bolus (arrow) moved down from pharynx, through esophagus and into the stomach, but capsule remained lodged in upper esophagus.

Esophageal scintigraphy represents a significant advance in the ability to evaluate esophageal function. The technique is tubeless, quantitative, and can be used with "physiologic" boluses of varying physical and chemical composition.

It has been assumed that swallowed tablets or capsules pass unimpeded into the stomach unless motor or mechanical dysfunction of the esophagus is present. Although the sensation of tablets and capsules "sticking" in the esophagus is not rare, the finding that capsules commonly fail to pass from the esophagus in normal subjects was surprising. Equally unexpected was the observation that capsules may remain in the esophagus for periods up to 2 hr without the subject's awareness. Delays in esophageal transit of tablets and capsules take on added importance if the association between oral medications and esophageal inflammation is considered. Sporadic cases of esophagitis associated with oral administration of medications (*18*) such as potassium chloride (*19–22*), ferrous sulfate (*23*), tetracycline (*24*), and doxycycline (*25*) have been reported. The increased contact time between the esophageal mucosa and a potentially toxic chemical may be important in the pathogenesis of these lesions.

Our present observations suggest that one should avoid the common practice of administering tablets or capsules dry and/or giving medications to patients who are supine. Capsules should be swallowed only following a lubricating water bolus, then with water, and followed by a water chaser. In addition, the sitting or standing positions are preferred in order to increase the probability that a capsule will pass into the stomach. Finally, although there is ample endoscopic evidence of esophagitis in symptomatic patients who have ingested oral capsules or tablets, there is need to investigate the importance of incomplete or delayed esophageal emptying of medicated gelatin capsules on their therapeutic action.

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