Assessment of Distal Esophageal Function in Patients with Hiatal Hernia and/or Gastroesophageal Reflux

DAVID B. SKINNER,* M.D., DONALD J. BOOTH, MAJOR, USAF, MC

From the Department of Surgery, The Johns Hopkins University School of Medicine, The Johns Hopkins Hospital, Baltimore, Maryland, and the General Surgery Service, Wilford USAF Hospital, Lackland AFB, Texas

To ASSESS distal esophageal function in patients with hiatal hernia or gastroesophageal reflex, four tests have been employed in 351 patients during the past 6 years. Results have been compared to values obtained in 91 healthy volunteers. The indications, technics, clinical applications, and resuts of these esophageal function tests have been reviewed.

Methods

The four esophageal function tests include: manometry, acid perfusion, pH reflux, and acid clearing. Currently these are all performed at one sitting requiring approximately 1 to 1½ hours. Patients are studied while fasting. A standard esophageal motility catheter consisting of three water-filled polyvinyl tubes (ID 0.034 inches) bonded together with distal openings spaced 5 cm. apart is passed, similar to a nasogastric intubation, into the stomach. The proximal ends of the polyvinyl tubes are connected to pressure transducers and in turn to a multichannel recorder. In recent studies, small amounts of water have been infused continuously through the tubes at a rate insufficient to cause a pressure rise in the system, usually .076 ml./min. to each tube. Previously catheters were flushed intermittently but not continuously during the study. A long pH electrode (Beckman #39042) is passed into the midesophagus in similar fashion and connected to a pH meter attached in turn to the recorder.

Manometry. Once all three tube openings are in the stomach, the catheter is withdrawn in 0.5 cm. increments as measured in the nostril. As each tube opening crosses the gastroesophageal junction, a high pressure zone (HPZ) is normally identified which can be characterized by its length in centimeters, and mean pressure elevation greater than that recorded in the stomach (Fig. 1). When all three openings have been withdrawn across the HPZ into the esophagus, the patient is requested to swallow so that peristalsis can be evaluated. The remainder of a complete esophageal motility study can be performed as indicated.

Acid Perfusion. After manometry is completed, the tubes are placed with their openings 5, 10, and 15 cm. above the gastroesophageal high pressure zone. Pressures are recorded through the middle and distal tips. The patient continues to lie supine. Fluid is perfused into the esophagus through the proximal opening 15 cm. above the HPZ. Initially 0.9% sodium chloride solution is perfused at the rate of 6
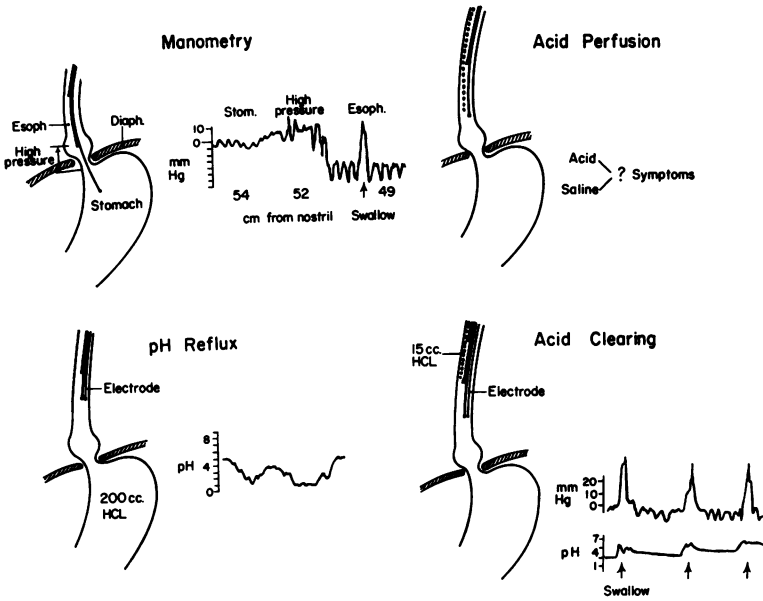
FIG. 1. Diagram showing the position of the motility catheter and pH electrode for performance of the four esophageal function tests. See text for details of each test.

ml./min. for 10 minutes. Without allowing the patient to know that any change has been made, the perfusion is switched to 0.1N HCl at the same rate for 10 minutes or until the patient spontaneously complains of symptoms or pain. The perfusion is switched back to saline and the patient's response is again noted. A positive acid perfusion test is recorded when the patient's own symptoms occur during perfusion of acid and not during perfusion of saline. The production of symptoms other than those for which the patient is being evaluated, or the production of symptoms by perfusion of both saline and acid are not regarded as a positive test. The production of esophageal motor disturbances during acid perfusion unaccompanied by the patient's typical symptoms is not judged a positive test. As the results of this test are judged by the patient's symptomatic response, it is essential that the patient report his sensations or symptoms spontaneously and without prompting or interpretation by the observer.

pH Reflux. The pH electrode and catheter are advanced into the stomach, and 200–300 cc. of 0.1N HCl are inserted.

Tubes are flushed and withdrawn so that the distal tip is again 5 cm. above the HPZ. Intragastric pH is recorded and the electrode is withdrawn in 1 cm. increments across the gastroesophageal junction until it is 5 cm. above the HPZ. Intraesophageal pH and pressures are recorded while the patient performs deep breathing, Valsalva, Muller, and coughing maneuvers in the supine, right and left side down, and head down positions. A fall in pH to less than 4.0 is regarded as evidence of reflux. After a fall in pH, delay is made for spontaneous clearing, swallowing, or flushing of the tubes to permit the pH in the esophagus to rise before the next maneuver is attempted. The number of drops in pH, and the proportion of the study during which intraesophageal pH remains below 4.0 permits grading of reflux semiquantitatively from 0 to 3+.

Acid Clearing. The pH electrode and catheter remain in position 5 cm. above the HPZ. Through the proximal tube opening, 10 cm. above the pH probe, 15 cc. of 0.1N HCl are introduced into the esophagus. Intraesophageal pH and pressures are monitored. The patient is instructed to

TABLE 1. *Patients Evaluated*

	Patients	pH Reflux	Manometry	Acid Perfusion	Acid Clearing
A. Normals	91	91	91	0	28
B. Evaluated before therapy	306	306	304	129	202
C. Evaluated only after surgery	45	43	45	8	27
Total	442	440	440	137	257
Radiography in Group B: Hiatal hernia	200	200	198	89	131
No hiatal hernia	85	85	85	33	55
No x-ray	21	21	21	7	16
Reflux symptoms in Group B: Typical	135	135	133	58	84
Atypical	162	162	162	71	118
None	9	9	9	0	0

swallow at 30-second intervals, and the number of swallows required to elevate the pH to 5.0 is recorded. With acid in the esophagus, a rise in pH generally occurs only with peristalsis.

In each patient, the results of each test were correlated with the presence of a hiatal hernia if a barium swallow radiographic study was performed, and the patient's symptoms depending upon whether they were typical or atypical for gastroesophageal reflux. Symptoms were judged typical if heartburn, pain, and regurgitation were reported to be aggravated by postural maneuvers such as stooping or lying. All other upper abdominal or chest symptoms were judged atypical. The results of the manometric, acid perfusion, and acid clearing tests were correlated with the pH reflux test which was found to be the most sensitive diagnostic maneuver for determining reflux.

Clinical Material (Table 1)

A) **Normal Subjects.** Esophageal function tests were performed in 91 individuals who had no present or previous symptoms of upper digestive tract disease. The nature of the test was explained to each subject, and his voluntary permission to participate was obtained. Seventy-nine subjects were healthy men between 16 and 25 years old. Eleven men and one woman between 26 and 65 years old had other unrelated illnesses. The manometry and pH reflux tests were performed in all 91 subjects. The acid clearing test was employed in 28. The acid perfusion test was not performed in the normal subjects since they were all asymptomatic, and a postive test requires reproduction of the patient's symptoms.

B) **Abnormal Patients Evaluated Before Treatment.** In 306 patients who had hiatal hernia demonstrated radiographically or symptoms suggesting upper digestive tract disease, esophageal function tests were performed prior to determining the need for or instituting treatment. Two hundred had a radiographically demonstrated hiatal hernia. One hundred and thirty-five had typical symptoms of gastro-

TABLE 2. *pH Reflux Test Results*

Patient Group:	Normal (0–1+)	Abnormal (2–3+)	Significance (x^2 test)
Normal	89	2 (2%)	
Hiatal hernia	114	86 (43%)	
No hiatal hernia	61	24 (28%)	$p < 0.02$
Symptoms			
Typical	62	73 (54%)	
Atypical	116	46 (28%)	$p < 0.001$

esophageal reflux, 162 had atypical symptoms, and nine had no symptoms. Among these patients, all 306 had a pH reflux test, 304 had esophageal manometry, 129 had an acid perfusion test, and 202 had an acid clearing test. Fifty-seven had a second set of esophageal function tests performed after surgical treatment. The findings from esophagoscopy were available in 61 patients studied before treatment.

C) **Patients Evaluated Only After Operation.** In 45 patients, esophageal function tests were performed only after surgical treatment for an upper digestive tract disorder. When combined with the 57 patients who had pre- and postoperative evaluations, the effects of operation on distal esophageal function were evaluated in 102 patients.

Of the total 442 patients or subjects studied, 24 were evaluated at the Massachusetts General Hospital, 107 at USAF School of Aerospace Medicine, 227 at Wilford Hall USAF Hospital, and 34 at The Johns Hopkins Hospital.

Results and Interpretations

pH Reflux Test. From the results obtained in the 91 normal subjects, normal values were determined. Sixty-three had no drop in pH at all during the test. Twenty-six had one or two transient drops in pH with rapid return towards neutral. This was graded 1+ reflux, and was considered to be a normal finding. More frequent falls in pH were graded 2+ reflux. When the pH in the esophagus remained low throughout most of the study and multiple falls in pH occurred, grade 3+ reflux was recorded. One normal subject each displayed 2+ and 3+ reflux, yielding a false positive rate of 2.2%.

Among the 306 patients who had some upper abdominal or chest symptoms, and /or a hiatal hernia, 113 were found to have no reflux, 71 had 1+ reflux, and 122 had grade 2 or 3+ reflux. The results of the pH reflux test correlated significantly with the radiographic and symptomatic evaluations (Table 2). In all instances in which gastroesophageal reflux was seen radiographically, an abnormal reflux test was observed. However there were a number of instances in which abnormal reflux was identified by the pH electrode, but no reflux was seen radiographically. Considering the low false positive rate for the pH reflux test in normal subjects, this confirmed that radiography was not a particularly sensitive method for diagnosing reflux. Undoubtedly false negative pH reflux tests occur, but in the absence of some better definition for reflux, the number of false negative tests cannot be stated accurately.

Because the pH reflux test actually measures reflux into the esophagus under standardized conditions, because of the sharp distinction between normal and abnormal, and because of the low false positive rate in normal subjects, the pH reflux test defines abnormal gastroesophageal reflux. When an abnormal result is observed, further investigations and treatment for the condition are indicated.

Tuttle and Grossman tested competency of the cardia by observing the location and slope of the gradient in acid levels between stomach and esophagus as the pH electrode was withdrawn across the cardia.[20, 21] This maneuver was analyzed in 61 normal controls. A normal, sharp gradient at the level of the manometric high pressure zone was found in 47, but

a gradual rise in pH occurring over 4 or more centimeters was observed in three subjects (5%), and displacement of the pH gradient 2 or more centimeters proximal to the HPZ occurred in 11 additional subjects (18%). The false positive results from the pH withdrawal test are too high for satisfactory clinical interpretation, so this technic is no longer used.

Manometry. The length of the gastroesophageal high pressure zone and its mean pressure were compared to the presence of hiatal hernia, typical or atypical symptoms, and a normal or abnormal reflux test. At the Massachusetts General Hospital and USAF School of Aerospace Medicine, all manometry was performed with tubes that were intermittently flushed, but not continuously infused. The results from these manometric tests using uninfused catheters were compared to those obtained in all instances in which continuously infused catheters were employed. There were no significant differences in mean pressures of the HPZ in studies performed with uninfused catheters, when normals and groups having a hiatal hernia, typical symptoms, atypical symptoms, normal, or abnormal reflux test were compared. The mean length of the HPZ was significantly greater ($p < 0.01$) in the groups having hiatal hernia or symptoms when compared to normal subjects. There were no significant differences in mean HPZ lengths between groups having a normal or abnormal reflux test.

Using continuously infused catheters, there were no significant differences in mean HPZ pressures between the group having a hiatal hernia and that without a hiatal hernia, or between groups with typical or atypical symptoms. There was a significant difference ($p < 0.001$) between the group who had normal reflux tests (mean 7.3 ± 2.3 mm. Hg) and that having abnormal reflux tests (mean 3.7 ± 2.1 mm. Hg). The mean length of the HPZ was sig-
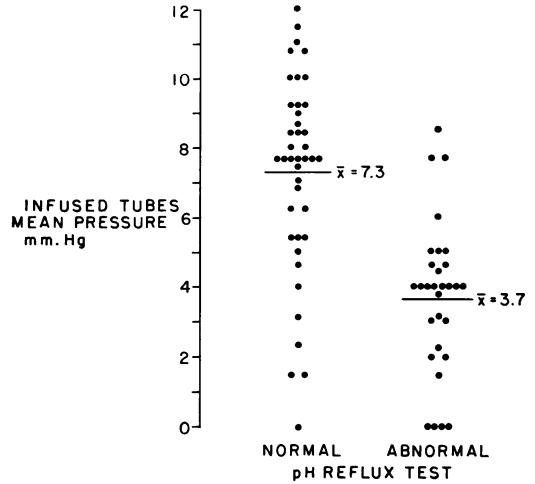

FIG. 2. Pressure elevations measured by continuously infused tubes in the gastroesophageal high pressure zones of patients with normal or abnormal reflux. Although there is a statistically significant ($p < 0.001$) difference between the mean values, the overlap is such that manometry alone is not satisfactory for determining competency of the cardia.

nificantly greater ($p < 0.05$) in those having hiatal hernias (mean 3.6 ± 1.0 cm.) compared to those without hiatal hernia (mean 3.1 ± 0.7 cm.), whereas there were no significant differences between the HPZ lengths in groups with normal or abnormal reflux tests.

These results confirmed the findings of Winans and Harris,[24] and Pope[14] that the use of motility catheters not continuously infused was of no value in determining competency of the cardia. When continuously infused catheters were employed, HPZ pressures were significantly greater in patients with a competent cardia judged by the reflux test compared to those with an incompetent cardia. However the range of pressures observed was sufficiently broad that the results of the manometry cannot be considered diagnostic of an incompetent cardia in an individual patient (Fig. 2). Manometry by both the continuously infused and uninfused technics discriminated statistically between patients having a hiatal hernia and those which did not. Correlation of HPZ length with

TABLE 3. *Acid Perfusion Test Results*

Patient Group	Negative	Positive	Significance (x^2 test)
Hiatal hernia	36	53 (60%)	NS
No hiatal hernia	16	17 (52%)	
Symptoms:			
Typical	16	42 (72%)	$p < 0.05$
Atypical	38	33 (46%)	
pH Reflux:			
Normal	39	37 (49%)	$p < 0.02$
Abnormal	16	37 (70%)	
Acid Clearing:			
Normal	30	16 (35%)	$p < 0.001$
Abnormal	21	53 (72%)	

hiatal hernia was described by Code *et al.*[7] However, in our studies, there was again great overlap, suggesting that hiatal hernia was better diagnosed radiographically.

In patients suspected of having abnormal reflux, manometry is valuable in excluding motor abnormalities of the distal esophagus such as scleroderma, spasm, and achalasia, which may be present in patients with an incompetent cardia or mimic reflux symptoms. The other role of manometry is to determine the location of the gastroesophageal junction in centimeters from the nostril as a guide to placing the catheters and pH electrode used in the other esophageal function tests.

Acid Perfusion Test. Since a positive acid perfusion test depended upon production of the patient's spontaneous symptoms, the test was not performed in normal subjects. The results of the acid perfusion test are shown in Table 3. There was no correlation between this test and the presence of a hiatal hernia. There were significant correlations between the acid perfusion test and the patient's symptoms ($p < 0.05$), the pH reflux test ($p < 0.02$), and the acid clearing test ($p < 0.001$).

The main value of this test in our experience is to assist in evaluating patients with atypical symptoms to determine whether

the symptoms may be of esophageal origin. In a patient with atypical symptoms which are reproduced by the acid perfusion test and in whom an abnormal pH reflux test is present, the symptoms may be regarded as resulting from incompetency of the cardia. Treatment for this condition may be undertaken in the expectation that the symptoms, although atypical, may respond. Since the acid perfusion test relies upon the patient's symptomatic response, and it has been noted previously that symptoms are not a good guide to pathologic reflux or the extent of esophagitis,[17] the acid perfusion test by itself is not a very sensitive or reliable guide to diagnosing the presence of reflux or esophagitis in individual patients.

Acid Clearing Test. The acid clearing test was initially performed in 28 normal subjects who had grade 0 pH reflux tests. Each of these normal subjects cleared the bolus of acid in 10 swallows or less causing a pH rise to 5.0 or above. This was taken to represent a normal acid clearing test. Persistence of a low pH in the esophagus for more than 10 swallows was accordingly judged abnormal acid clearing. The rate of swallowing has been shown previously to be unrelated to the results of the clearing test.[4]

When the acid clearing test results were analyzed, a positive correlation was found with the presence of hiatal hernia (*p* <

TABLE 4. *Acid Clearing Test Results*

Patient Group	Normal	Abnormal	Significance (x^2 test)
Normal	28	0	
Hiatal hernia	50	81 (62%)	$p < 0.05$
No hiatal hernia	30	25 (45%)	
Symptoms:			
Typical	27	57 (68%)	$p < 0.02$
Atypical	58	60 (51%)	
pH Reflux:			
Normal	75	48 (39%)	$p < 0.001$
Abnormal	11	68 (86%)	

0.05), the nature of the patient's symptoms ($p < 0.02$), the pH reflux test ($p < 0.001$), and the acid perfusion test ($p < 0.001$), Table 4.

To test the hypothesis that patients with abnormal acid clearing would be more likely to have esophagitis, comparisons were made between the various parameters and the visible changes at esophagoscopy in 61 patients. Esophagitis was defined as definite reddening of the mucosa, or more severe changes including exudates, ulcerations, or fibrosis. No statistically significant correlations were observed between the esophagoscopic findings and the presence of hiatal hernia, typical symptoms, abnormal pH reflux tests, or positive acid perfusion tests (Table 5). The greatest discrimination between patients with esophagitis or no visible esophagitis was achieved by the acid clearing test. Seventy per cent of the former and 36% of the latter had abnormal acid clearing, a correlation of borderline significance ($0.1 > p > 0.05$). It has been recognized that the gross observations at esophagoscopy did not correlate well with microscopic examination of biopsies in patients with minimal or no visible esophagitis.[16] Currently biopsies are taken routinely at the time of esophagoscopy in an effort to diagnose esophagitis more precisely. Esophagitis is a diagnosis which can be made only by gross or microscopic observation of inflammation in the esophagus. The acid clearing test is the indirect method which appears to have the strongest correlation with the presence or absence of esophagitis. This supports the theory that prolonged contact between regurgitated gastric contents and the esophagus may result in esophagitis, or conversely that esophagitis caused prolonged acid clearing. In either case, an abnormal acid clearing test coupled with an abnormal pH reflux test strongly suggests that the patient may have esophagitis and

TABLE 5. Correlation of Gross Esophagoscopic Findings with Other Evaluations

	Esophagoscopy		Significance (x^2 test)
	No Esophagitis	Esophagitis	
Hiatal hernia	18	27 (60%)	NS
No hiatal hernia	5	9 (64%)	
Symptoms:			
Typical	10	21 (68%)	NS
Atypical	14	15 (52%)	
pH reflux test:			
Normal	10	10 (50%)	NS
Abnormal	13	27 (68%)	
Acid perfusion:			
Negative	8	7 (47%)	NS
Positive	6	14 (70%)	
Acid clearing:			
Normal	7	4 (36%)	$0.1 > p > 0.05$
Abnormal	10	22 (70%)	

has a severe reflux problem which should be evaluated by esophagoscopy and treated.

Postoperative Studies

In 102 patients, esophageal function tests were employed to evaluate the results of operation for upper alimentary tract disorders. Most postoperative studies were performed within 30 days following operation, although some patients were studied up to 15 years later. In seven patients, early postoperative studies were followed by a subsequent pH reflux test performed 6 to 12 months later. The results did not change between the early and late examinations.

The results of the postoperative studies are presented in Table 6. The variety of operations performed, and variability in time following operation preclude the use of these figures to establish which of the operations is superior in treating or preventing gastroesophageal reflux. However the data do suggest some trends which may be confirmed by additional postoperative studies.

TABLE 6. Results of Postoperative Studies

Operation	pH Reflux Test		Acid Clearing Test	
	Normal	Abnormal	Normal	Abnormal
Belsey Mark IV	16	0	1	7
Nissen Fundoplication	13	0	3	10
Hill	3	1	1	2
Hill+Vag.+Drain.	6	2	3	5
Collis	4	0		
Collis+Vag.+Drain.	1	3		
Allison	5	7	2	5
Hiatal Repair	3	1		2
Hiatal Repair+Vag.+Drain.	10	8	7	5
Vag.+Drain. only	7	6	5	4
Gastric Resection	3	1	3	0

Operations designed to prevent gastro-intestinal reflux generally incorporate several principles including creation of an intra-abdominal segment of esophagus, creation of an esophagogastric flap valve mechanism, closure of the crus around the esophagus, and preservation of the innervation, and the mucosal and muscular pattern of the cardia.[1, 22] Procedures which incorporate these principles have been described by Belsey,[18] Nissen,[12] Hill,[9] and Collis.[8] One of these repairs was employed by the authors in 35 patients as the sole procedure to treat abnormal reflux usually associated with a hiatal hernia. In only one of these 35 patients, was an abnormal reflux test observed after operation. Before operation, 22 of 28 patients studied had abnormal reflux. The acid clearing test remained abnormal in the majority of these patients indicating that the disorder in esophageal function was not readily reversed by operation or that the reconstruction itself interfered with emptying of acid from the esophagus. Since the repairs prevented reflux of gastric contents into the esophagus, a persisting abnormality in acid clearing would seem of little consequence. Fourteen patients treated by the Belsey Mark IV or Nissen fundoplication operations had esophageal manometry performed with continuously infused tubes

before and after surgery. The mean postoperative gastroesophageal pressure elevation was 5.8 mm. Hg greater than the preoperative level ($p < 0.001$). Acid perfusion tests were performed in 12 of these patients following operation. The test was negative in ten and positive in two patients who had no reflux, illustrating that acid sensitivity in the esophagus may persist after reflux is corrected.

In 14 patients, anti-reflux operation (Belsey in 1, Nissen in 1, Hill in 8, and Collis in 4) was combined with vagotomy and antrectomy or pyloroplasty, generally performed because of concomitant peptic ulcer disease. In contrast to the patients treated by reconstruction of the cardia alone, five of the 14 patients with combined operations had abnormal reflux tests following operation. In none of these 49 patients was hiatal hernia seen after operation by radiographic studies, and none had typical symptoms of reflux at the time of the study.

Although the conditions under which these observations were made prevent direct comparison of one group of patients with another, the postoperative results raise several clinical suggestions. Clearly the operations incorporating principles designed to prevent reflux are successful in doing this, at least in the early postoperative pe-

riod. The clinical results of large series of patients treated by each of these four repairs have already established the effectiveness of these operations in relieving the patients symptoms and abnormal radiographic findings.[8, 9, 16, 18] Of the 49 patients who received anti-reflux procedures, six had abnormal reflux following operation, and it was of interest that a vagotomy and gastric procedure had been added to the reconstruction in five. This finding supports our opinion that vagotomy and a gastric procedure should be performed only in those patients in whom it is clearly indicated for active ulcer disease. Patients who are to undergo operation for peptic ulcer disease should be screened by esophageal function tests and radiography for findings suggesting hiatal hernia or reflux, which should be treated by an anti-reflux procedure at the time of gastric surgery.

Discussion

Esophageal function tests have a clearly defined role in evaluating gastroesophageal reflux and hiatal hernia. These tests are not necessary for diagnosis in patients with typical symptoms of heartburn and regurgitation aggravated by posture who have hiatal hernias and esophageal reflux demonstrated by x-ray. When such patients are identified clinically, esophagoscopy should be performed to assess the extent of esophagitis and provide a basis for choosing medical or surgical treatment. Surgery is generally offered to those patients who have destruction of esophageal mucosa with ulcer formation or more advanced esophagitis, or those patients who have received adequate medical therapy for at least 6 months without satisfactory control of symptoms even though esophagitis may not be visible.

A number of patients are encountered in whom symptoms are atypical, a hiatal hernia may not be identified, or reflux cannot be shown radiographically. In these pa-

tients, the esophageal function tests serve as a screening procedure to select those with abnormal reflux who may develop complications such as esophagitis, stricture, bleeding, or aspiration of gastric contents into the lungs, and who should undergo esophagoscopy as a guide to treatment. Esophageal function tests may provide the only method to diagnose reflux in patients without hiatal hernia whose symptoms suggest that they are suffering from gastroesophageal reflux. Previously a number of these patients did not receive treatment for abnormal reflux because of normal radiographic findings. Similarly in patients with hiatal hernias, and atypical symptoms, it is often difficult to determine whether the hiatal hernia should be regarded as the cause of the symptoms. In such patients, the esophageal function tests have proved invaluable in determining whether the patient's symptoms might be attributable to this cause or to other abnormalities. In patients with unusual syndromes which can be caused by reflux such as referral of all symptoms to the cervical esophagus (globus hystericus), anginal-like symptoms, or chronic occult pulmonary aspiration, the esophageal function tests are helpful in making the correct diagnosis.

Esophageal function tests are helpful also in patients with two or more concomitant abnormalities such as hiatal hernia with cholelithiasis, pancreatitis, peptic ulcer disease, or angina pectoris. It may be difficult to decide which condition is more significant and whether the hiatal hernia requires therapy. In general, if the pH reflux, acid clearing, and acid perfusion tests are all normal in a patient with a small hiatal hernia and another lesion, the hiatal hernia may be ignored therapeutically. An exception to this appears to be the patient who requires operation for peptic ulcer disease. Because of the increased incidence of reflux noted in this series and by other authors following gastric operations,[25] it

seems wise to reconstruct the cardia in such patients at the time that the gastric procedure is performed.

Because of the current widespread interest in treatment methods for gastroesophageal problems, and the variety of operations proposed, a particularly important use of esophageal function tests is in the evaluation of surgical results. It is only by obtaining objective data of this type that the relative merits of different surgical approaches will ultimately be decided, as the clinical results in controlling symptoms and x-ray abnormalities have not proved to be entirely reliable in pre- or postoperative evaluations. Finally these technics have proved valuable from an investigative point of view in obtaining further understanding of the mechanisms controlling function of the gastroesophageal junction.[19]

Tuttle and Grossman [20] introduced the use of the pH electrode to assess competency of the cardia, and with Betarello [3, 21] reported series of patients evaluated by the pH electrode withdrawal technic. Because of the high incidence of false positive results obtained with this technic in the current study, we do not feel that this is a satisfactory method for defining reflux, and prefer to measure gastroesophageal reflux by falls in pH at a level 5 cm. above the high pressure zone under standardized conditions. Other workers such as Morgan and colleagues,[11] Sandmark,[15] Piccone, Gutelius, and McCorriston,[13] and Vandervelde and Carlson [23] have employed pH electrode technics to diagnose gastroesophageal reflux. By standardizing the conditions under which pH in the esophagus is monitored as described by Kantrowitz et al.[10] the incidence of false positive reflux tests has been reduced to a clinically acceptable level of 2%. Based upon available evidence, monitoring pH in the esophagus currently represents the most sensitive method for measuring gastroesophageal reflux.

The acid perfusion test was introduced by Bernstein, Fruin and Pacini as a means to differentiate pain of esophageal origin from that of angina pectoris.[2] This test has continued to prove useful for this purpose and for determining whether symptoms can be attributed to esophageal origin. However the acid perfusion test may be overinterpreted, if employed as a guide to the presence of esophagitis,[6] which must utimately be diagnosed by observation of the esophagus. In the current study, the acid perfusion test did not correlate significantly with the visible findings of esophagitis. The acid clearing test introduced by Booth, Kemmerer, and Skinner [4] provides a more sensitive indicator of disordered esophageal function causing or resulting from esophagitis. Delayed emptying of the esophagus appears to be specifically related to acid, as studies employing alkaline solutions as a marker substance show no correlation between the presence of esophagitis or esophageal reflux.[5]

Summary

Two or more esophageal function tests, manometry, pH reflux, acid clearing, and acid perfusion, were performed in 91 normal volunteers, 306 patients having hiatal hernia and/or upper digestive tract symptoms, and 45 patients studied only after surgical treatment. Results from each test were correlated with the patient's symptoms, radiographic findings, and the other tests. The pH reflux test satisfactorily defined abnormal gastroesophageal reflux. Manometry was useful as a guide to placement of the pH electrode and catheter for other studies. The acid perfusion test was valuable in determining whether the esophagus was a source of atypical symptoms. The acid clearing test provided the best discrimination between patients who did or did not have visible esophagitis by esophagoscopy. The tests were employed to evaluate the results of operation in 102

patients. Other applications of esophageal function tests are discussed.

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