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# Simultaneous measurement of intraluminal pressure and *p*H in the stomach and oesophagus

## With special reference to the diagnosis of hiatal hernia and hiatal incompetence

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A short survey is given of the theoretical background for the simultaneous measurement of intraluminal pressure and *p*H in the oesophagus and stomach as well as the method used in the paper presented. In 20 of 23 patients with symptoms of regurgitation this was sustained by the *p*H measurement (87%). In only 20% was incompetence demonstrated radiologically. The *p*H measurement is of especial value in the diagnosis of oesophageal reflux. The value of simultaneous pressure measurements is to ascertain the position of the electrode distally or proximally to the oesophageal hiatus. Thus we suggest that pressure and *p*H measurements are mandatory in future post-operative follow-up examinations in patients operated upon for hiatal herniae.

Hitherto, clinical symptoms, radiographic examinations, and oesophagoscopy have been the main diagnostic guides in organic disease of the oesophagus. The aim of this study has been to develop a method which, in combination with conventional examinations, may contribute to greater accuracy in the evaluation of hiatus hernia and incompetence of the cardia.

In cases of sliding hiatal hernia one often faces diagnostic and therapeutic problems. Furthermore, objective evaluation of the results of operative treatment, considering the herniation as well as the incompetence of the cardia, can be difficult.

In a study (Borgeskov, True Pedersen, and Frederiksen, 1964) from this clinic, 46 patients operated upon for sliding hernia were re-examined seven years after their operation. Six patients were found to be free of symptoms, but they all had recurrences, at the radiological examination, of either the sliding hernia or regurgitation caused by cardiac incompetence. In nine patients whose symptoms had persisted it was not possible to demonstrate any recurrence radiologically or by oesophagoscopy. In other words, in one third of the patients we found inconsistency between objective and symptomatic recurrences. Other workers (Gertz, Regout, and Thomsen, 1951; Stensrud, 1954; Werner and Wiklund, 1959; Husfeldt, Andreassen, Lindenberg, and Thomsen, 1960; Paulson, Shaw, and Kee, 1962; Nygaard, Linaker, and Helsingen, 1964; and Therkelsen, 1966) have confirmed this disagreement.

A more objective evaluation of the condition of the patient seemed important and had been made possible by simultaneous intraluminal measurement of the hydrogen ion concentration as well as of the pressure in the stomach and oesophagus. Reports on pressure studies carried out with electric pressure transducers in combination with electronic amplification began to appear some 10 years ago (Creamer, 1955).

Numerous studies have since been published about pressure conditions in the oesophagus. A monograph by Code, Creamer, Schlegel, Olsen, Donoghue, and Andersen was published in 1958. In Scandinavia, Sandmark (1963a) studied and described these conditions. Experience in simultaneous pressure and *p*H registration was published by Hill, Chapman, and Morgan in 1961 together with a study by Tuttle, Bettarello, and Grossman (1960). Tuttle introduced a small *p*H electrode together with a pressure pick-up into the stomach. 0·1 N Hydrochloric acid, 300 ml., was instilled into the stomach and the electrode together with the pick-up were drawn upwards. A *p*H of below 4, extending at least 4 cm. above the hiatus, was considered as regurgitation.

Measurement of *p*H in the terminal part of the oesophagus gives an objective means of determining the presence or absence of peptic activity.

Significant peptic activity occurs in a *p*H range from 1 to 5. The peptic activity is maximal at a *p*H of 2·3, falls to 20% at a *p*H of 4, and is absent at a *p*H of 5 (Hill *et al.*, 1961). In normal subjects one finds at the cardia a sharp change of *p*H from about 1 in the stomach to a level well outside the peptic range in the terminal oesophagus. Correspondingly, one finds a pressure inversion zone at this level at which the intragastric positive pressure becomes a negative intraoesophageal pressure while pulling the measuring device upwards. The mean resting pressure inside the oesophagus is normally below atmospheric pressure as it reflects the negative intrathoracic pressure. In mean pressure curves one finds in normal subjects two zones with an elevated pressure above the mean gastric pressure. The lower pressure zone probably corresponds to the 'gastro-oesophageal sphincter' and is situated at the level of—or just above—the diaphragm.

The upper pressure zone is situated at the level of the pharyngo-oesophageal sphincter (Hamit and Raymond, 1962). The hiatus itself can be identified by means of the respiratory peaks because the pressure increases during inspiration while the catheter is in the stomach, whereas the pressure decreases during inspiration with the catheter in the chest. This 'Pressure Inversion Point' (PIP) corresponds to the diaphragmatic hiatus in normal subjects as well as in patients with a hiatal hernia.

For pressure measurements in the oesophagus one can use open small-calibre polyethylene catheters or closed catheters with a small pressure-sensitive balloon in the end. These balloon-catheters amplify the pressure undulations. Open pressure catheters record the pressure changes more precisely (Kelley, 1964). Pressure conditions in hiatal herniae consist of a zone with an elevated pressure corresponding to the gastro-oesophageal sphincter as well as a double pressure inversion point and a pressure plateau inside the territory of the sphincter. Respiratory reversal is considered by Code *et al.* (1958) to be the most important single indicator of a hiatal hernia.

Figure 1 shows the pressure and *p*H findings in various kinds of hiatal hernia and incompetence of the cardia in various combinations.

We have not tried to examine motility conditions inside the oesophagus.

## METHODS

In the present series we used open small-calibre polyethylene catheters which were filled with water and

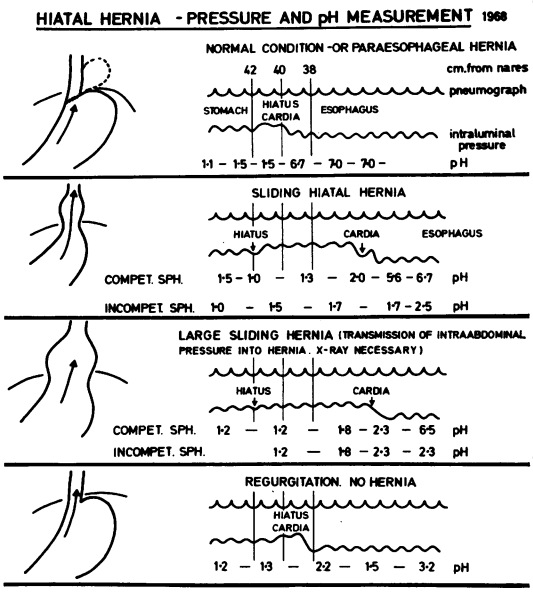


FIG. 1. *Intraluminal pressure and* p*H recordings in various conditions of gastro-oesophageal function.*

connected to a Statham pressure transducer (0–5 cm. Hg). The transducer was positioned 11 cm. above the table with the patient in the prone position, *i.e.*, at the level of the cardia. The transducer was attached to a self-recording amplifier and the *p*H was recorded with a radiometer (6282/SP) tube connected to a radiometer, *p*H-meter for continuous readings. A calomel reference electrode was placed on one arm of the patient. Nowadays a combined calomel electrode is used (Rune, 1968). The pressure catheter and the glass electrode were attached to each other with pieces of adhesive tape placed 5 cm. apart. The combined electrode and catheter were introduced through the nose after anaesthetizing the patient with leostesin (R) spray in order to avoid vomiting and gastro-oesophageal regurgitation. The electrodes were passed into the abdominal part of the stomach and this was verified by simultaneous recording of the pressure curve on an oscilloscope. In cases of achlorhydria, 0·5 mg. histamine was given subcutaneously. In some cases 10 ml. of 0·1 N HCl was given through the pressure tube. During simultaneous recording of pressure curves and *p*H, the tube was slowly withdrawn. At the *p*H inversion point we continued to draw the tube upwards a further 5–10 cm. and the examination was continued in the Trendelenburg position combined with Valsalva's manœuvre to provoke regurgitation of acid gastric contents into the oesophagus. Figure 2 shows a curve obtained from a normal subject while Fig. 3 shows the conditions in a patient suffering from a hiatal hernia.

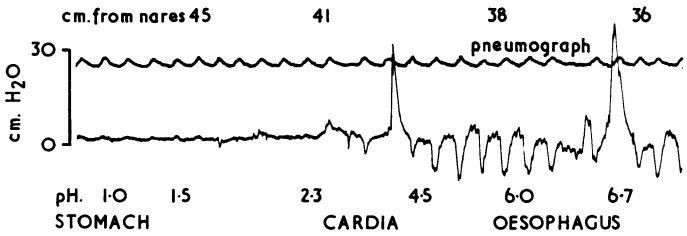


FIG. 2. *Normal pH and pressure recording. At the top the respiratory movements are recorded.*

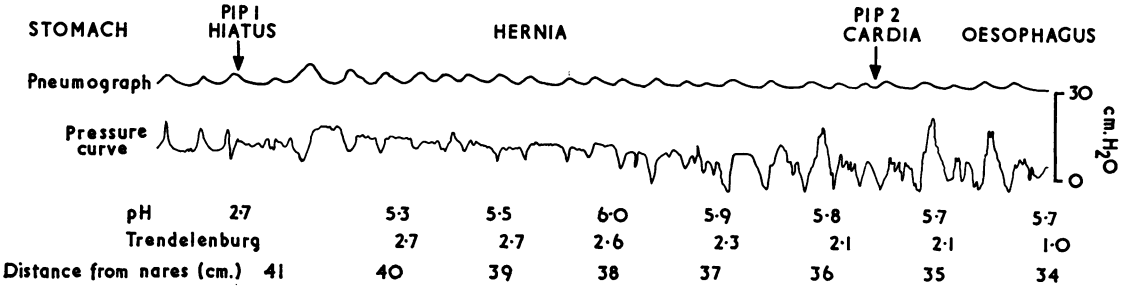


FIG. 3. *pH and pressure measurements in a patient with sliding hiatal hernia and regurgitation of gastric contents into the oesophagus.*

## MATERIAL

Simultaneous pressure and *p*H measurements were carried out pre-operatively in 15 patients, of whom 10 complained of symptoms corresponding to hiatal incompetence with regurgitation. Five patients complained of unspecified symptoms mostly as a feeling of oppression (Table).

In nine of the 10 patients with symptoms of regurgitation this was sustained by the intraluminal *p*H measurement.

On radiographic examination regurgitation into the oesophagus was demonstrated only in three patients while in seven a hernia was found; in two this was radiologically of the paraoesophageal type.

At operation a hiatal hernia of the sliding type was found in nine of the 10 patients with symptoms of regurgitation. In the last patient there was a combination of a sliding and a paraoesophageal hernia.

Among the five patients without symptoms of regurgitation radiological examination revealed paraoesophageal hernia in three and sliding hernia in two. The *p*H and pressure measurements showed a sliding hernia in two patients, one of them with regurgitation of gastric contents into the oesophagus. In one patient a combined sliding and paraoesophageal hernia was demonstrated.

In two patients the findings were normal as one would expect in cases of paraoesophageal hernia. The diagnosis was in all cases confirmed at operation (Table).

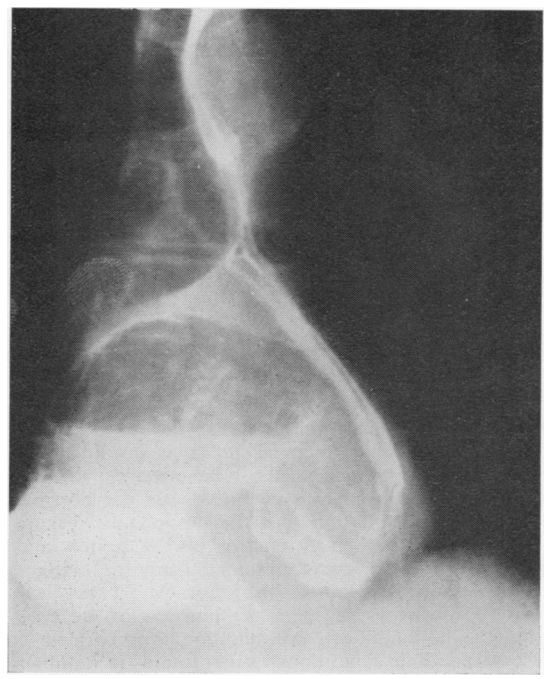

FIG. 4. *Radiograph showing large paraoesophageal hernia.*

## TABLE

PRE-OPERATIVE FINDINGS IN 15 PATIENTS

| Patient No./Sex/Age | Symptoms | Oesophagoscopy | Radiological Appearance | Pressure Curve | *p*H Measurement | Operation Notes |
|---|---|---|---|---|---|---|
| 286/65 W 56 | Oppression | Normal | Paraoesophageal hernia | Normal | Normal | Paraoesophageal hernia |
| 312/66 W 51 | Regurgitation | Oesophagitis | Hernia no regurgitation | Normal | Normal | Sliding hernia |
| 254/65 M 55 | Regurgitation | | Hernia no regurgitation | Hernia | Regurgitation | Sliding hernia |
| 277/66 M 63 | Regurgitation | Oesophagitis | Hernia no regurgitation | Hernia | Regurgitation | Sliding hernia |
| 365/65 W 54 | Regurgitation | Oesophagitis | Paraoesophageal hernia | Unreliable | Regurgitation | Sliding hernia |
| 20/66 W 51 | Regurgitation | | Paraoesophageal hernia | Hernia | Regurgitation | Combined hernia |
| 591/66–67 W 69 | Oppression | Slight oesophagitis | Paraoesophageal hernia | Combined hernia | Normal | Combined hernia |
| 16/67 W 71 | Oppression | | Sliding hernia no regurgitation | Hernia | Normal | Sliding hernia |
| 729/66–67 M 53 | Regurgitation | | Hernia no regurgitation | Normal | Regurgitation | Sliding hernia |
| 89/68 W 64 | Oppression | Slight oesophagitis | Sliding hernia no regurgitation | Hernia | Regurgitation | Sliding hernia |
| 88/68 M 57 | Regurgitation | Regurgitation | Sliding hernia + regurgitation | Hernia | Regurgitation | Sliding hernia |
| 684/67 M 46 | Regurgitation | Oesophagitis | Sliding hernia + regurgitation | Hernia | Regurgitation | Sliding hernia |
| 892/67 W 63 | Oppression | | Paraoesophageal hernia | Normal | Normal | Paraoesophageal hernia |
| 930/67 W 47 | Regurgitation | | Sliding hernia + regurgitation | Hernia | Regurgitation | Sliding hernia |
| C184/67 W 62 | Regurgitation | Regurgitation | Sliding hernia | Hernia | Regurgitation | Sliding hernia |

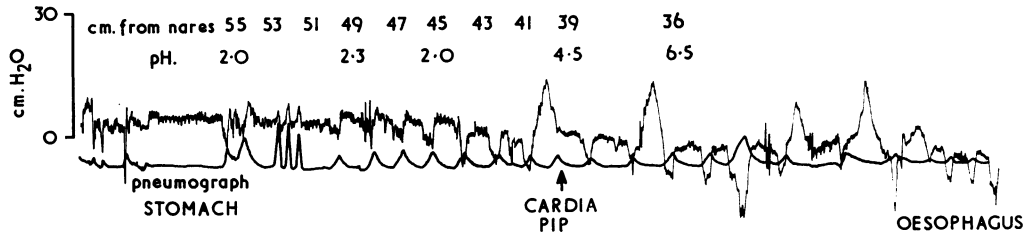


FIG. 5. p*H and pressure measurements in a patient with combined sliding and paraoesophageal hernia (same patient as in Figs* 4 *and* 6).

In patient 591/66-67 the diagnosis was a combined hernia found at pressure measurements. We found a *p*H of 2 situated 55 cm. from the nares but the pressure tube showed that it was still intrathoracic. It was not possible to pass the tube distal to the diaphragm and, by pulling the tube upwards, a sharp inversion of the *p*H was seen but it was not possible to provoke regurgitation into the oesophagus. Figure 4 shows the radiological picture of the hernia and Fig. 5 the pressure curve obtained from it. It seems that the tube remained intrathoracic. From the schematic drawing in Fig. 6 the position of the tube inside the hernia during examination is illustrated.

Corresponding conditions were found in another patient (64/67) but the diagnosis was not verified operatively.

Seventeen patients were examined post-operatively. Fourteen had herniae of the sliding type, one had a paraoesophageal hernia, and two had mixed herniae at operation.

Eight patients had symptoms of regurgitation. Regurgitation was demonstrated radiologically in two patients but *p*H measurement revealed regurgitation in seven.

Ten patients who had symptoms of a hiatal hernia were not operated upon for various reasons. Five of the patients complained of regurgitation and four of oppression. Radiographs showed a hernia in seven but there was no regurgitation. In two, intraluminal pressure measurement showed a hernia while *p*H measurement in three confirmed symptoms of regurgitation.

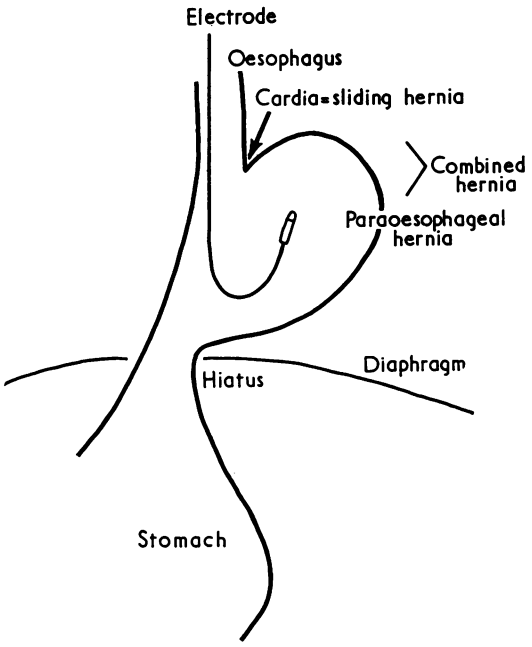


FIG. 6. *Shows the electrode during measurement in a patient with combined sliding and paraoesophageal hernia. It was not possible to pass the electrode into the intra-abdominal part of the stomach. This is shown in Figure 5.*

## DISCUSSION

From the data presented it is our opinion that continuous measurement of the *p*H in the stomach and oesophagus, with the patient in different positions, is useful in the diagnosis of incompetence of the cardia. Twenty-three patients had clinical signs of regurgitation. In only five of these had the diagnosis been confirmed radiologically, and in these the diagnosis was confirmed by *p*H measurements. The *p*H measurement revealed regurgitation in 15 of the 23 patients. Thus in 20 patients (87%) we obtained objective confirmation by *p*H measurement of the patients' symptoms while radiological examination was positive in only 20%.

The discrepancy between the radiological findings and the patients' symptoms may be explained by the fact that the results of radiological examination depend on the technique used. It is possible to over- and under-diagnose the presence of a sliding hernia. The viscosity of the contrast medium, the duration and size of the compression used, and the position of the patient during examination may influence the result. If one uses a high viscosity contrast medium together with heavy compression on the abdomen with the patient prone in Trendelenburg's position it is possible to obtain false positives. It is possible by this technique to overcome the physiological sphincter of the cardia and thus obtain regurgitation into the oesophagus (Sandmark, 1963b). In cases of paraoesophageal hernia neither *p*H nor pressure measurements give information and this diagnosis can only be made radiologically. Pressure measurements in patients with sliding hernia or a combined hernia, verified radiologically or found at operation, were abnormal in 15 out of 18 cases. In sliding herniae we found a zone of increased pressure for a longer distance than normal corresponding to the gastro-oesophageal sphincter. It was possible in one case with certainty to demonstrate a double pressure inversion point which, according to Code, Kelley, Schlegel and Olsen (1962), is the most important finding that indicates a hiatal hernia. It is emphasized that the result of intraluminal oesophageal and gastric pressure measurements should be interpreted with care. Only with the supplement of radiographs have we ventured to make the diagnosis of a sliding hernia on a patient. The pressure measurements alone have in no case had any therapeutic effect on the patient. This is in accordance with the findings of Piccone, Gutelius, and McCorriston (1965) and Adkins, Bhayana, and Blades (1966). On the other hand, pressure measurements have been indispensable in determining the position of the *p*H electrodes. In our hands, it was only the measurement of *p*H which had clinical significance during the recording of gastro-oesophageal regurgitation. Therefore we consider this examination essential in order to evaluate the results of operative treatment in patients with a hiatal hernia and incompetence of the cardia.

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