# Does the diameter of glass electrodes imply restriction in clinical use?

**G. Cargill (Paris)**, J.P. Vergnet (Ecully)

*Volume The Esophagogastric Junction Chapitre pH-measurements*

Glass electrodes with an internal reference electrode are preferable for pH-recording [1], but have an inconveniently large diameter (3 - 4.5 mm), making them less suitable for infants and small children. The problem is not the passage through the nostrils, but that an electrode of 4 mm diameter might influence esophageal function in a 6-month-old baby [2].

From an unpublished study reported by Vandenplas [2] with combined pressure pH-recording, it became clear that the larger the diameter of the electrodes, the more frequently the patient had to swallow. Frequent swallowing might have a normalizing effect on pH monitoring data, since the more the patient swallows, the more primary peristalsis will be induced and the better the esophageal clearance will be. Nasopharyngeal intubation increases salivary secretion [3] for a period of 4 hours, but probably does not affect the result of a 24-hour pH-recording. The small diameter of glass micro-electrodes (Microelectrode MI506 approximately 1.2 mm) or antimony electrodes (approximately
2.1 mm) makes them preferable for infants. These glass and antimony electrodes require an external cutaneous reference electrode, which is one more possible cause of erroneous measurement.

Antimony electrodes, with a diameter of approximately 1.5 mm, exist for premature babies but are too flexible for older infants.

The ion sensitive field effect transistor (ISFET) electrodes have, like antimony electrodes, a small diameter; this technology is comparable with that of glass electrode, and seems to be a solution for the future.

Two other parameters are important for a comfortable examination: the flexibility of the probe and the length of the non flexible part of the electrode.

We use four kinds of electrodes: antimony electrodes (Synectics G91-9011 Monocrystant Antimony pH Catheter), microelectrodes (Microelectrode MI 506), combined glass electrodes (Ingold 440 M3 and Heito pH gastric probe).

The diameter of the glass microelectrode is 1.2 mm, smaller than an antimony electrode, but the flexibility of this kind of probe is too important and a rolling-up is possible during the passage through the nostrils, through the pharynx, or into the esophagus. So, we use microelectrodes as second glass electrode for multiple measurements with a combinated glass electrode.

The diameter of the Heito stomach combined electrode is more important than Ingold combinated electrode (3 ± 0,2 mm vs 3 mm), but the flexibility, and the acceptability of this probe are better. Furthermore, the hardening of this electrode with the number of examinations is less important, due to the composition of the probe (PVC for Ingold combined glass electrode - diameter 3 mm, and silicone with a diameter of 4 ± 0.1 mm for Heito stomach electrode). Silicone cable appears to be more comfortable with a more important diameter.

For the passage through the nostrils, the diameter and the length of the rigid part of the electrode is also an important factor for the comfort of the patient: with a too small diameter and an important rigid part, the patient feels a sensation of prick. Furthermore, this is an important factor of breaking of the central cable of the electrode.

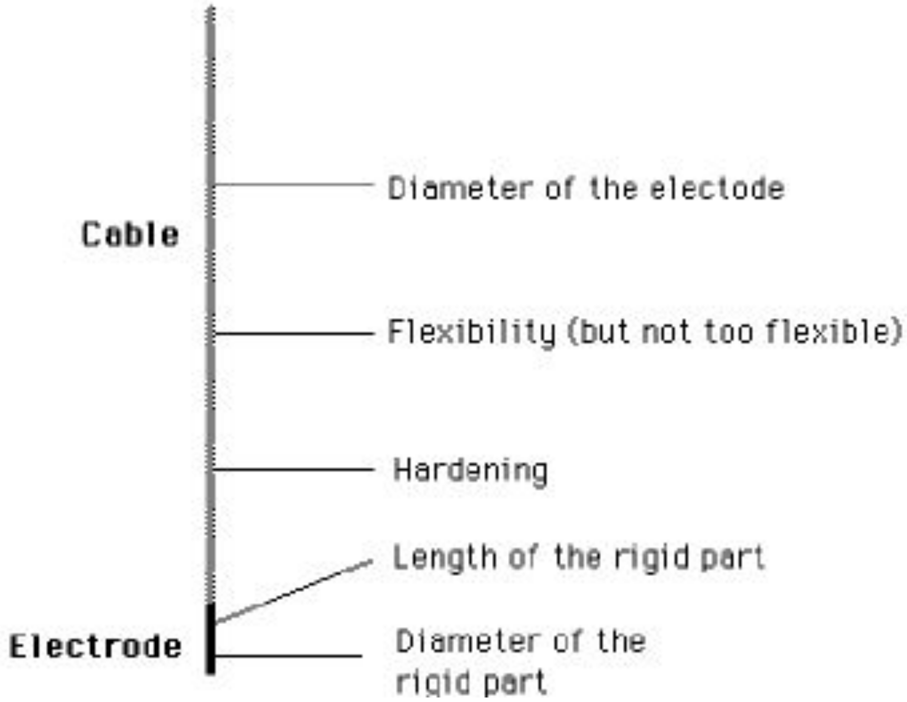

Figure 1. Different factors of acceptability of pH-electrodes.

Conclusion

The diameter of glass electrodes implies restriction in clinical use only in infants. The diameter is an important factor of comfort, but not the only one: flexibility and hardening of this electrode with the number or examinations are important, as is the length of the terminal rigid part of the probe. Furthermore, the flexibility of a very small diameter probe may be too important and a rolling-up is possible during the passage through the nostrils, through the pharynx, or into the esophagus.

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## What are the technical details of clinical relevance in pH-metry? What are the advantages and disadvantages of antimony electrodes?

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*Volume The Esophagogastric Junction Chapitre pH-measurements*

Each technology has advantages and disadvantages. For pH-metry, the diameter and the flexibility of antimony electrodes are an unquestionable advantage. What are the elements of comparison between antimony electrodes and other electrodes?

Antimony or glass electrodes are currently the most popular, although other types do exist like ISFET (ion sensitive field effect transisor) electrodes, plastic electrodes with polymeric membranes and telemetric capsules.

Comparisons with glass electrodes

The first comparisons between glass and antimony electrodes are due to Emde [1, 2]. These studies showed that, due to special phosphate free buffers and the need of the skin reference electrode, the calibration procedure of the antimony electrode is more susceptible to errors than it is with the combined glass electrode. The glass electrode is more stable, has a shorter response time, and a better accuracy; furthermore, its life time is much longer. Regarding the mechanical properties, the antimony electrode is smaller and easier to place and remove.

McLauchlan et al., in a comparative study [3], examined 3 pH electrodes: antimony electrodes with remote reference electrodes, glass electrodes with remote reference electrodes and combined glass electrodes with integral reference electrodes. In vitro studies showed that both glass electrodes were similar and superior to the antimony electrode with respect to response time, drift and sensitivity. The effect of the sitting of the reference electrode on the pH was examined in five volunteers. The pH reading using a remote skin reference electrode was higher by a mean of 0.3 pH units in the stomach, lower by 0.65 pH units in the duodenum and lower by 0.3 pH units in the esophagus than that simultaneously obtained with an intraluminal reference electrode. The glass electrode shows a linear response over the pH range 1 to 7. The antimony electrode is non linear, and shows consistent hysteresis.

Antimony electrodes require an external cutaneous reference electrode which is one more possible cause of erroneous measurement resulting from transmucosal potential difference. So, it is important that the cutaneous electrode and the contact gel used for the calibration be identical to those used for the recording, since all these factors will influence the pH measured [4]. If the environmental temperature is high, or the patient profusely sweats, the contact gel might dry, resulting in a less accurate conduction of the electric potential.

For Evans [5], the disadvantages of antimony electrodes are:

- a relatively short life of approximately 100 hours, as the pH sensing process is corrosive, this both oxidizes and removes metallic antimony from the surface of the electrode,
- the greater possibility of contamination of the pH sensitive surface with food debris and internal secretions due to the small physical size of the electrode surface,
- the incompatibility with equipment designed for glass electrode because of a ten-fold difference in output voltage and a low impedance.

For Perdikis et al. [6], in an in vitro and in vivo study, antimony electrodes are less suitable than glass electrodes for prolonged foregut pH monitoring. Antimony electrodes showed greater pH drift, and overestimated the pH shift in gastric juice of both high and low pH. During 24-hour esophageal pH monitoring in normals and gastroesophageal reflux disease (GERD) patients, antimony electrodes overestimated alkalinity. In GERD patients, the percentage of time pH < 4 was significantly underestimated. Four patients with positive DeMeester scores (for pH < 4) using glass electrodes, had normal scores when using antimony electrodes.

We agree with those studies but, in our experience, we found other differences between glass and antimony electrodes. For our own comparison, we used a combined glass electrode (Ingold 440-M3) associated with an antimony electrode from Synectics (G91-9011 Monocrystant Antimony pH Catheter) at the same level, 5 cm upon the lower esophageal sphincter (LES) (preliminary manometric study). The pH-meter is a pH60+ from LTI with two electronic cards, one for glass electrode and one for antimony electrode. Because skin reference may cause erroneous measurements, we use the internal reference of the glass electrode for both probes. Electrode potentials during the 22 hour esophageal mesurement were sampled at a measuring interval of one second and stored after digitalization in the data logger.

At the end of the mesurement the data were transferred from the data logger to a PC. Data were evaluated using programs written in the language C and running under the
Dos 6 operating system.

Antimony electrodes showed greater pH drift, and overestimated the pH shift during GER of both high and low pH. Furthermore, antimony electrodes overestimated the duration of reflux episodes and gave a greater time under pH4. The cause of those errors is the important noise recorded with the electrode. The recording of this electronic noise is possible because we used a large band frequency amplifier, ahead the measurement chain and the use of a high frequency sampling.

The noise on the curve changes the interpretation of the data. Sometimes, it seems more acid, sometimes it appears to be less acid than the reality. There is also an effect on the calculation of the duration of reflux episodes as we can see on the two DeMeester's tables (Table I).

**Table I.** Difference between the two electrodes on the DeMeester's table: noise induces a variation for the number of episodes of more than five minutes.

| | DeMeester's table with glass | *vs* antimony | nc |
|---|---|---|---|
| Percent of time pH < 4 | | | |
| Total | 3 | 4 | [illegible] |
| Recumbent | 2 | 3 | [illegible] |
| Upright | 4 | 5 | [illegible] |
| Number of total episodes | 28 | 38 | |
| Number of episodes > 5 min | 1 | 3 | [illegible] |
| Longest episode | 0:05 | 0:07 | 0: |
| Time at the beginning of the longest episode | 15:48 | 15:48 | |

Table II shows an important difference between the two electrodes: percents between 7 and 8 are important for the antimony electrode, with some values near 8 just after the calibration (see Figure 1 upper channel and Figure 2), but the most important drift during this examination is observed on the twelfth and sixteenth hour of our recording with stable values of the pH for glass electrode and an important drift for the antimony electrode associated with a very important noise.

**Table II.** Difference of the pH repartition during a recording with a combined glass electrode a antimony electrode (using the reference of the glass electrode).

pH-analysis

Total time: 23:55 — Upright: 16:06 — Recumbent: 09:53

Difference > 20%: **
Difference > 10%: *

| % of time between pH | 10 - 9 | 9 - 8 | 8 - 7 | 7 - 6 | 6 - 5 | 5 - 4 | 4 - 3 | 3 - 2 |
|---|---|---|---|---|---|---|---|---|
| Antimony electrode | 0 | 0 | 29 | 34 | 20** | 14 | 2 | 1 |
| | 0 | 0 | 23 | 39 | 17 | 13 | 6 | 2 |
| | 0 | 0 | 26 | 38 | 18** | 13 | 4 | 1 |
| Glass electrode | 0 | 0 | 0** | 3** | 66 | 15 | 1 | 0 |
| | 0 | 0 | 10* | 44 | 25 | 16 | 4 | 1 |
| | 0 | 0 | 6** | 26* | 42 | 15 | 3 | 1 |

Figure 1. Comparative curves: upper curve (channel 1) antimony electrode. Lower curve (channel 2) glass electrode.

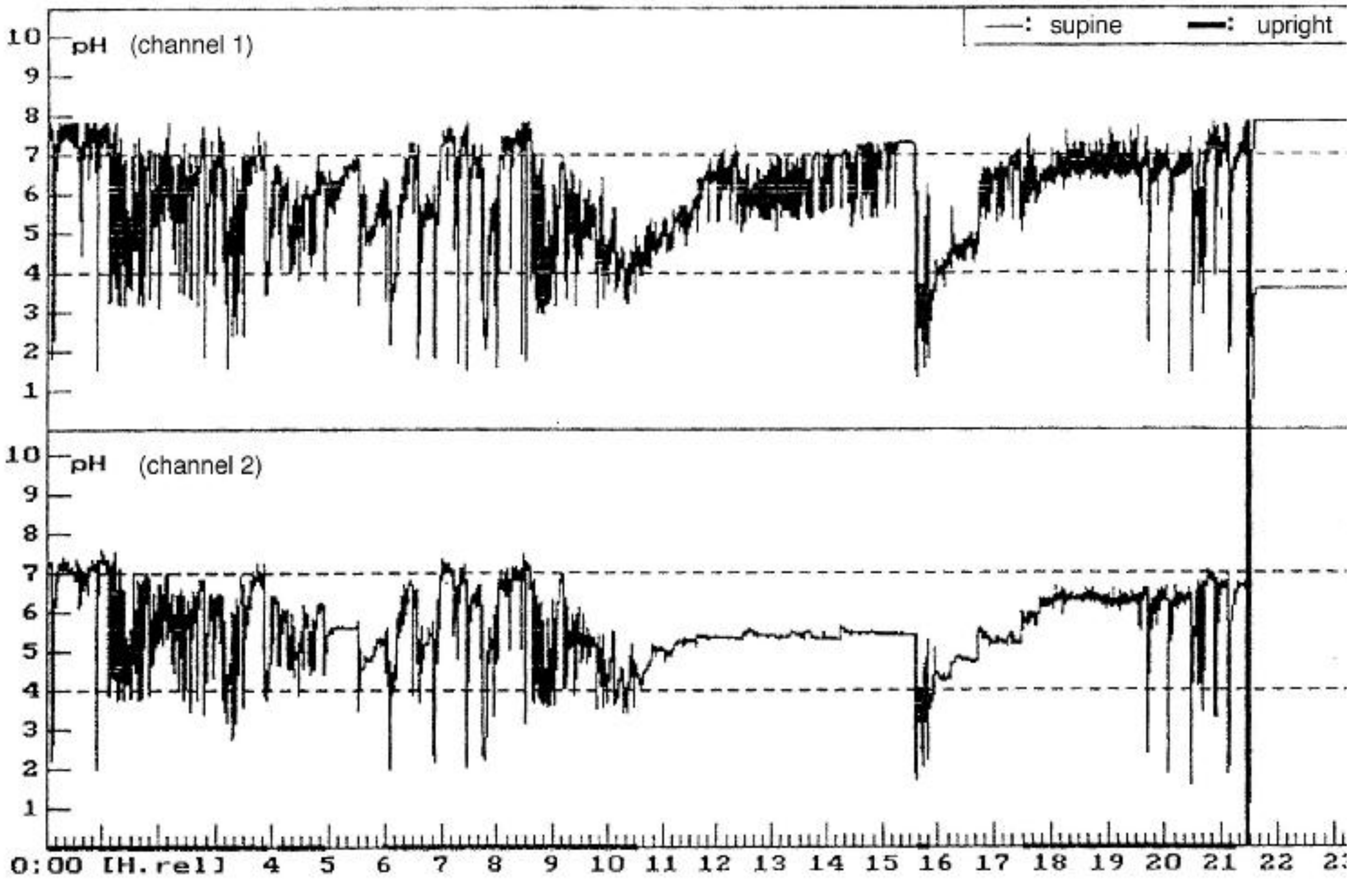



Figure 2. Comparative curves during the first part of the night: with the diminution of the salivary flow, pH goes down near 5 with poor variations with glass electrode. Conversely, with antimony electrode, pH rises to pH 7

with an important electronic noise.

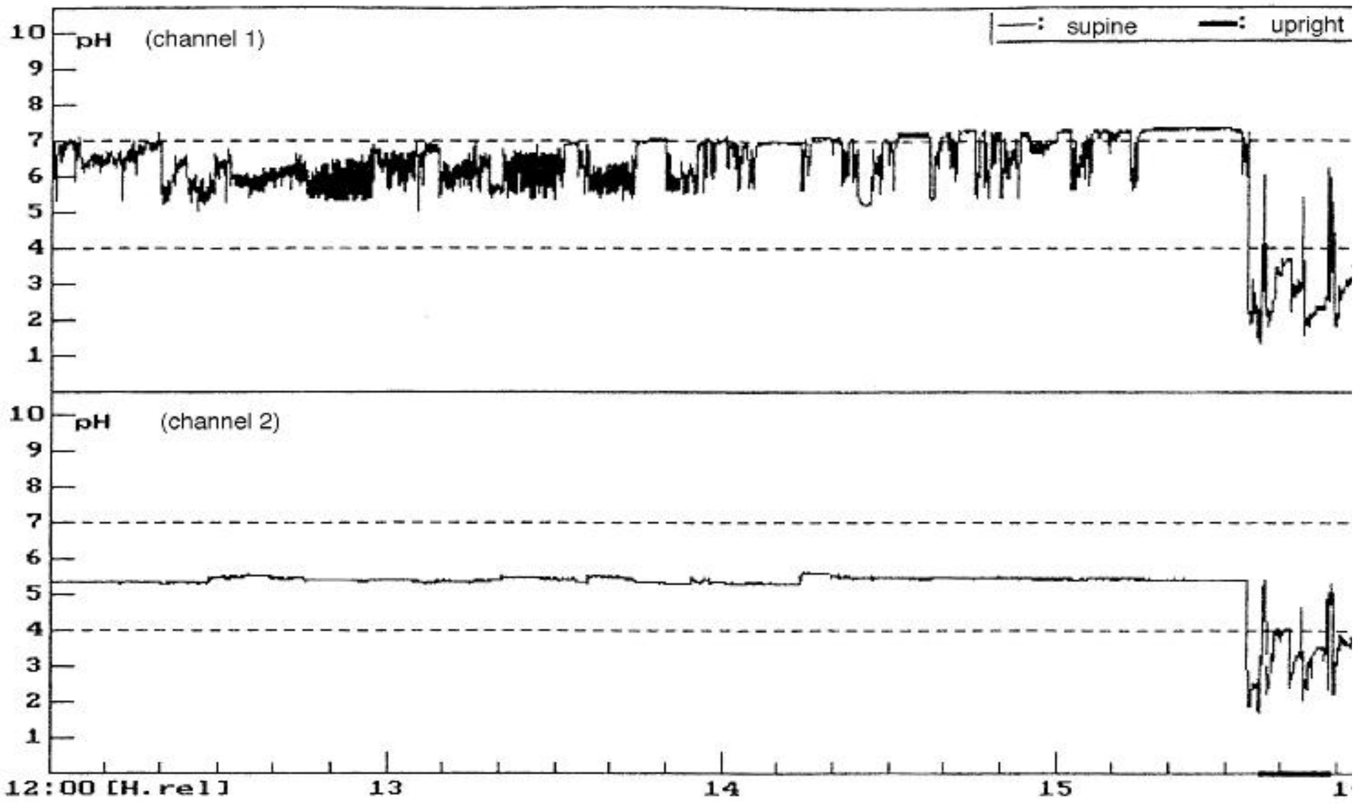



Figure 3 shows the same aspect after a reflux episode with glass electrode (channel 2). The study of the natural clearance is easy but, with antimony electrode, the drift and the noise do not allow this study with an important raising of the pH values at 4.40 p.m..

Figure 4 shows how the noise generates an uncertainty zone in which the measured pH may vary. The electronic noise may increase the duration of the reflux if the measured pH is close to the minimal values of the uncertainty zone generated by the noise; if these values are near maximum values, the duration of the reflux will be underestimated. In the same way, the noise may increase or decrease the pH values. This is an explanation of the differences between values observed with glass and antimony electrodes.

Figures 5, 6 and 7 show that the antimony electrode (channel 1) increases the number of reflux under pH 4 and the duration of reflux. Furthermore, the size of the drop of the pH is more important due to drift (and more important values before reflux).

Figure 3.

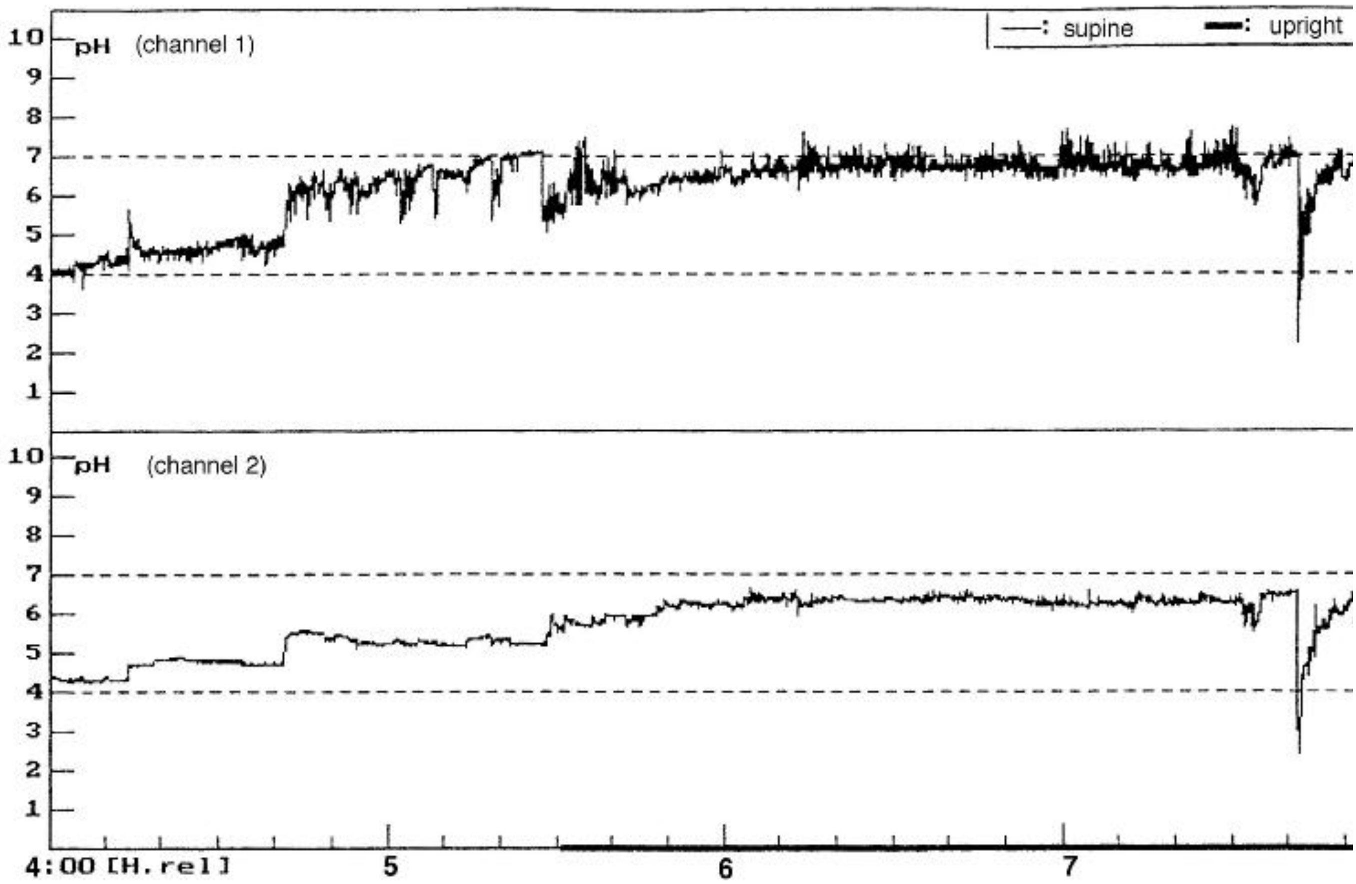



Figure 4.

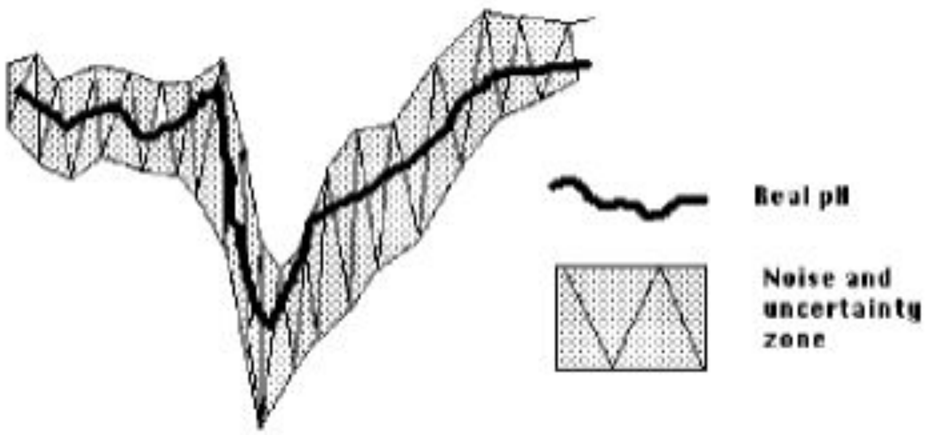
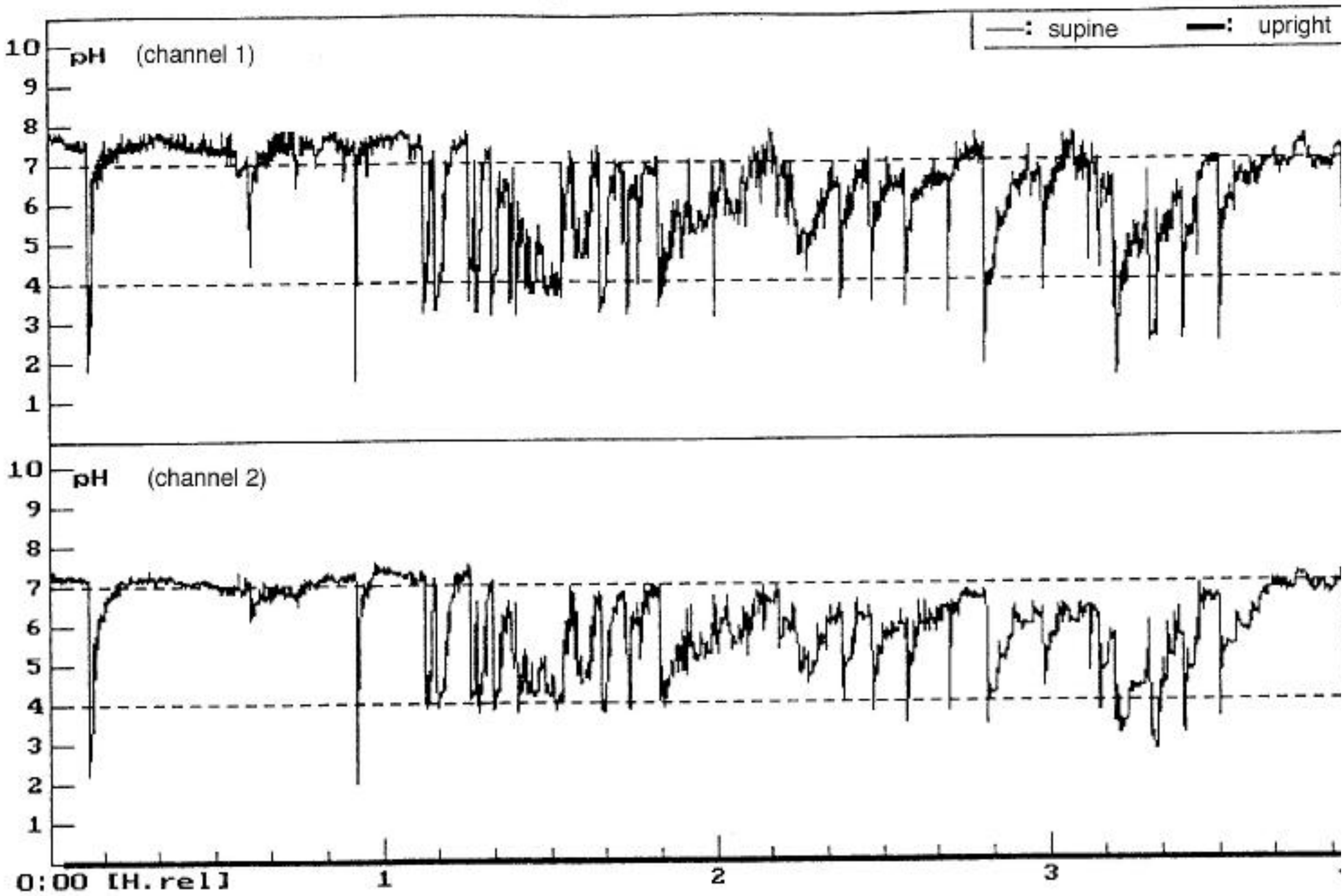


Figure 5.

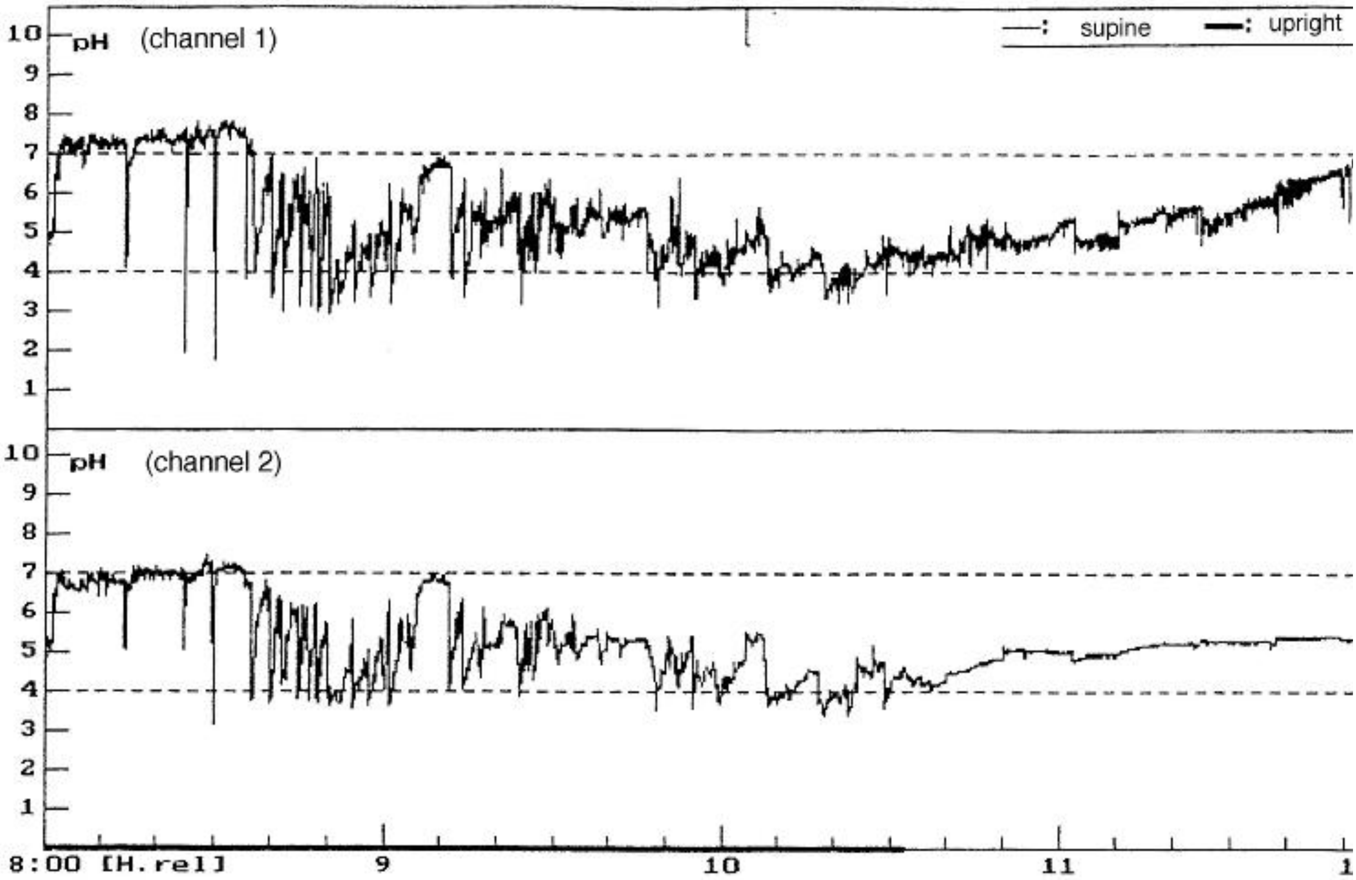


—: supine
▬: upright
pH (channel 1)
pH (channel 2)
10
9
8
7
6
5
4
3
2
1
0:00 [H.rel]
1
2
3

Figure 6.

The cost of the electrodes depends both on the local situation and the frequency with which they are used. Antimony electrodes are cheaper, but more measurements can be performed with a glass electrode, resulting in a comparable cost in most situations.

Figure 7.




Comparison with ISFET electrodes
A new sensor for long-term pH-monitoring do exist: the ISFET (ion sensitive field effect transistor) electrode, incorporating a reference electrode. This kind of electrode is comparable with a glass combined electrode [7] with a similar linear response over pH range 1.3 - 8, an equal response time, and an equal 24-hour drift.
Rutz [8] compared ISFET (Sentron catheter) and antimony electrodes (Synectics). Both electrodes recorded the pH 5 cm above the LES. The following parameters were calculated for each electrode: duration of recording, mean pH, median pH, total number of acid episodes, total number of acid episodes longer than 5 minutes, duration of the longest episode, total time with pH below 4 and area under curve. The ISFET electrode was more stable and reliable than the antimony electrode and its drift seems of minor importance.

Conclusions
Glass electrodes appear to be slightly more precise than antimony electrodes. Glass electrodes with an internal reference electrode are preferable, but have an inconveniently large diameter (3 - 4,5 mm) making them less suitable for infants and small children.
Antimony electrodes are not linear and present a consistent hysteresis, a greater drift, a longer response time and a lower sensitivity. Furthermore, there is an important noise during the recording, which causes errors.
In the future, ISFET electrodes which seem comparable with glass combined electrodes with a similar linear response, an equal response time and 24-hour drift combine, with a smaller size, the advantages of glass and antimony electrodes.

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# What are the differences between the two types of microtransducers: metal diaphragm strain gauges and piezoresistive silicon chips?

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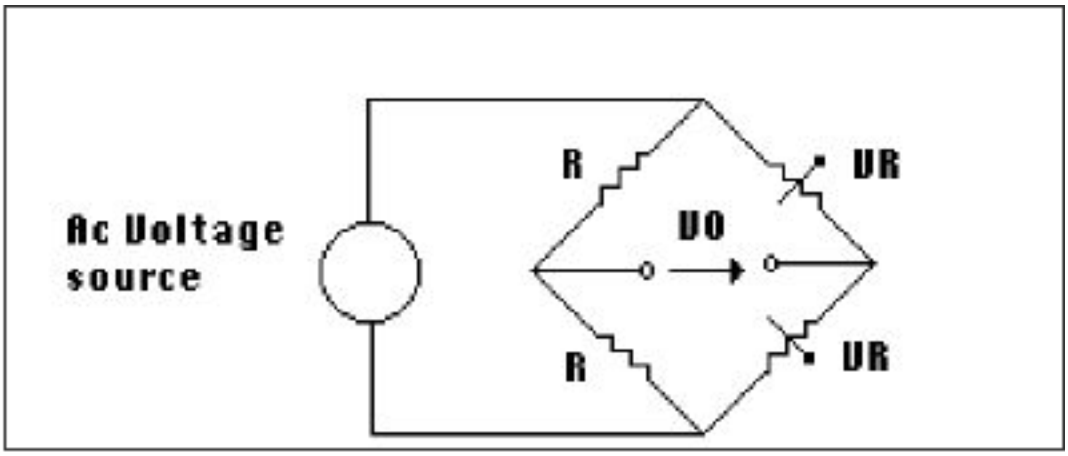
*Volume The Esophagogastric Junction Chapitre pH-measurements*

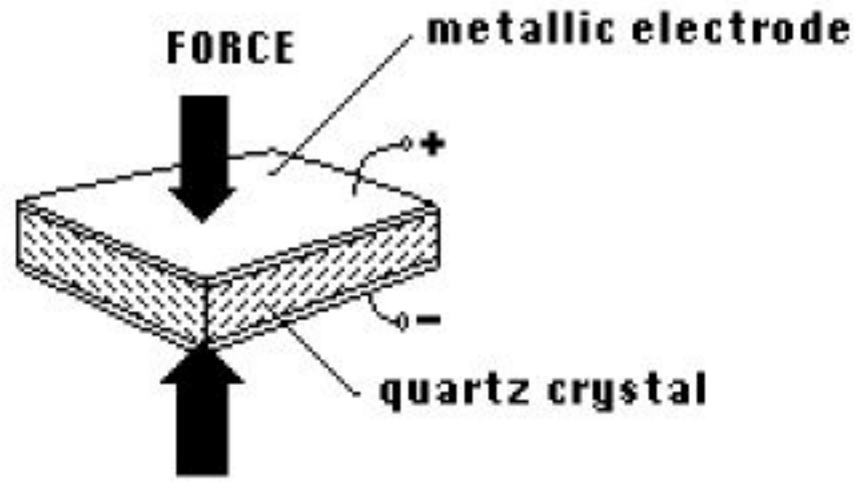
Microtransducers is an expensive technology. It cost is due to the fragility of the probe. The new studies of the rapid movements of the upper esophageal sphincter (UEP) [1] and the development of ambulatory studies have imposed this type of equipment
Principle of the measurement: the Wheatstone bridge
The electronic circuit for pressure measurement is the same one for the two technologies (metal diaphragm strain gauges and piezoresistive silicon chip): a Wheatstone "bridge" (Figure 1)

Figure 1. Wheatstone bridge.




The "bridge" operates on the principle that an input voltage is divided into the two fixed reference resistors in the left-hand "leg" and into the two measuring resistors in the right hand leg in proportion to the values of these components. The two reference resistors are of equal values, as are the two measuring devices at zero reading. However, as the pressure changes, the two measuring devices are no longer the same ones, as that between the two reference devices. This difference produces a voltage V0 at the output which, with power derived from the "bridge" source, drives a pen or a pointer.
The power source must be alternating in the case of inductance or capacitance bridges and can be either direct or alternating in the case of resistance (strain gauge) devices.

Metal diaphragm strain gauge: principle [2-4]
The principle of the metal diaphragm strain gauge is based on the property of metal resistance to change when subjected to a strain. The resistance variation is linked to the deformation by a mathematical relation :
DR = K DL
R L
where K is a constant which depends on the material of the gauge. In order to measure slight resistance variations, the gauge is electrically integrated in a Wheatstone bridge.
Piezoresistive silicon chip: principle [5, 6]
The piezoelectric effect was firstly described by Curie's brothers (in 1880), as the apparition of a voltage on the faces of a quartz crystal, proportional to the pressure applied on it (Figure 2). The electric resistance of a piezoresistive silicon chip changes with the pressure. This chip is included as a variable resistance in a Wheatstone bridge.
Metal diaphragm strain gauge: advantages
It is a very common technology, used for a long time, first by cardiologists for intracardiac measurements.
Figure 2. Piezoelectric effect: principle.




Metal diaphragm strain gauge: disadvantages
This transducer is very sensible to temperature, which affects the sensitivity and the zero. To correct this disadvantage, it is necessary to put two transducers head to foot. Furthermore, the gauge may have a memory of the deformation due to the pressure which implies two defects:
- the first one is an important hysteresis (the measure is not linear, and the curve in ascent measure is not the same as the curve in descent measure),
- the second one is a variability of the coefficient of sensitivity.
This implies to control and to change the sensitivity of amplifiers associated with the transducer.
Piezoresistive silicon chip: advantages
This kind of transducer is very linear (no hysteresis), its resolution is very high. The displacement of volume necessary for the measurement is very small (very low compliance - the maximum deformation for the total range of the measure is around one thousandth of millimeter). This specification implies that this kind of transducer has a frequency response still of 100 KHz.
Piezoresistive silicon chip: disadvantages
As metal diaphragm strain gauge, this transducer is very sensible to the temperature which affects the sensitivity and the zero. To correct this disadvantage, it is also necessary to put two transducers head to foot.
Applications
Ambulatory studies need an independent non perfused measuring system because of the important changes in position during the recording which affect the zero, and because the autonomy and the weight of this equipment are not compatible with a small size system and a limited energy supply. In the study of UES and pharyngeal contraction, it is necessary to have a very short rise time (pressure rise rate > 2000 mmHg/s) that cannot be supplied by perfused manometry (600 mmHg/sec) [7-9] . Wilson et al. [7] compared a catheter mounted transducer assembly with a modified sleeve catheter in the recording of tonic UES pressure and normal pharyngoesophageal motility.

Conclusions
Metal diaphragm strain gauges are older technologies than the piezoresistive silicon chip. The specifications of this last kind of transducer offer a best response time, a best linearity, a better respect of the physiologic signal, especially in the studies of rapid pressure variations like in the upper esophageal area.

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# What are the limitations of perfused side-hole and Dent sleeve manometry?

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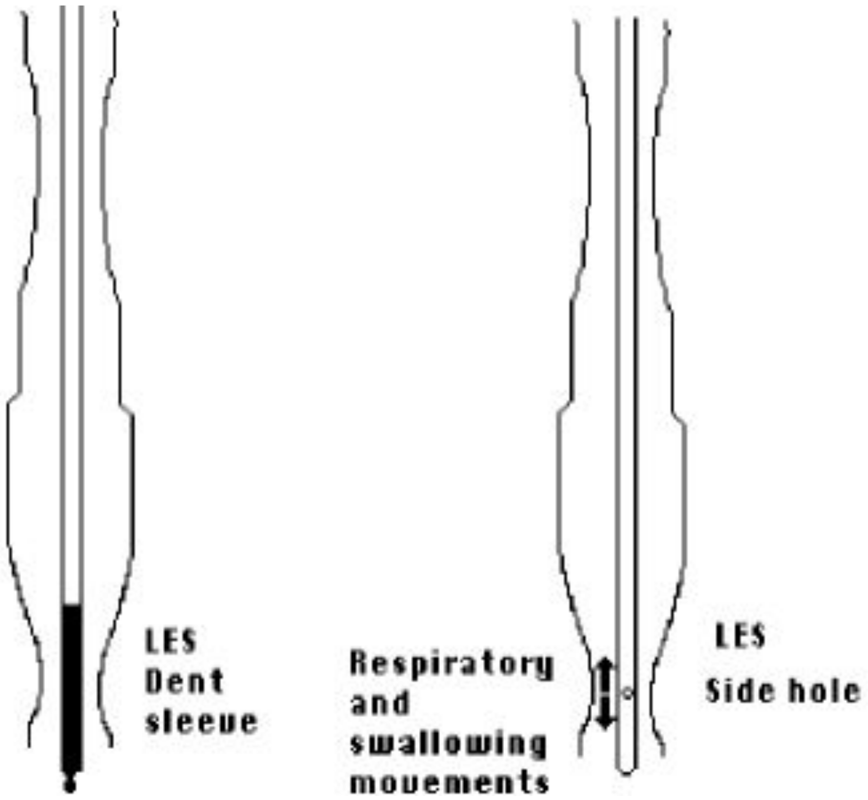
*Volume The Esophagogastric Junction Chapitre pH-measurements*

There are two main types of perfused manometry systems to perform today esophageal motility studies.
1) The perfused side hole system catheter, in which a perfused catheter is laterally open in the esophageal lumen. When the muscle obtures this hole during contraction, the pressure rises in the catheter and in the chamber of a pressure transducer. However, the catheter only reflects the activity of the small area opposite the side hole. Movement of a side hole sensor relative to the lower esophageal sphincter (LES) has been demonstrated with head movements, swallowing, respiration and abdominal compression [1] (Figure 1). The displacement of a side hole from the LES may mimic a relaxation.
Figure 1. Difference between the two types of catheters: on the right, movements may displace the side hole from the LES. With Dent sleeve, the measurement is effective on
5 to 6 cm and the LES is alway near the sleeve.




2) The Dent sleeve manometry catheter [2], in which one side of a 5 or 6 cm segment at the distal end is covered with a thin walled rubber sleeve that is glued along the catheter (Figure 2). The sleeve is constantly perfused with water by the proximal end, and the distal end is open to vent the perfusate. Sphincter squeeze acts on the sleeve to cause increased resistance to the flow of water through it. This increased resistance is directly related to the greatest squeeze acting on the sleeve.

Today, probes offer a combination of side holes (for the study of the body of the esophagus and to localize the LES) and of one sleeve (for the study of the LES) (Figure 3).

Figure 2. Sleeve.

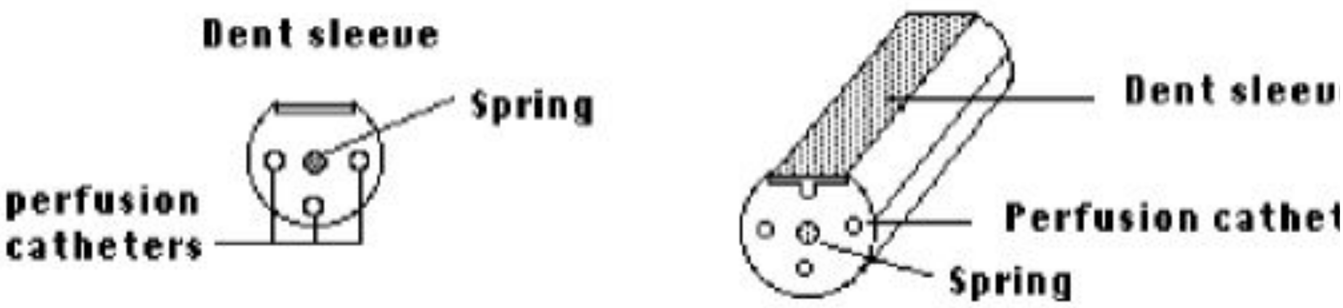
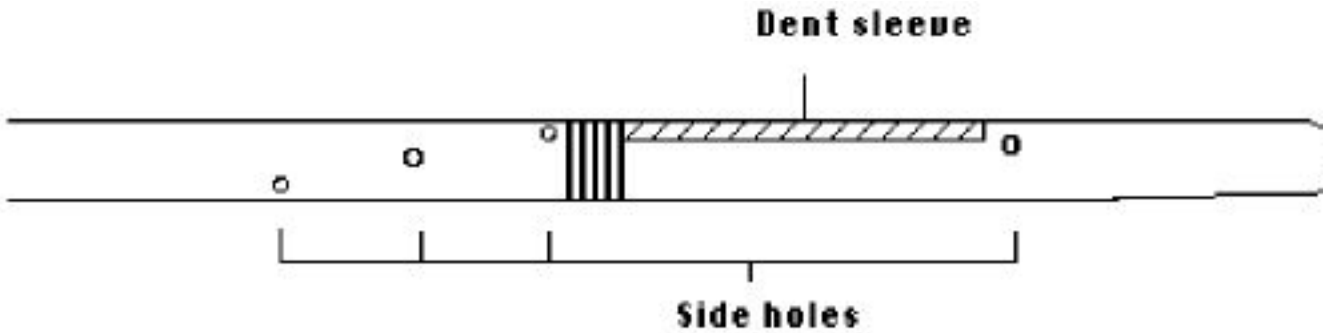
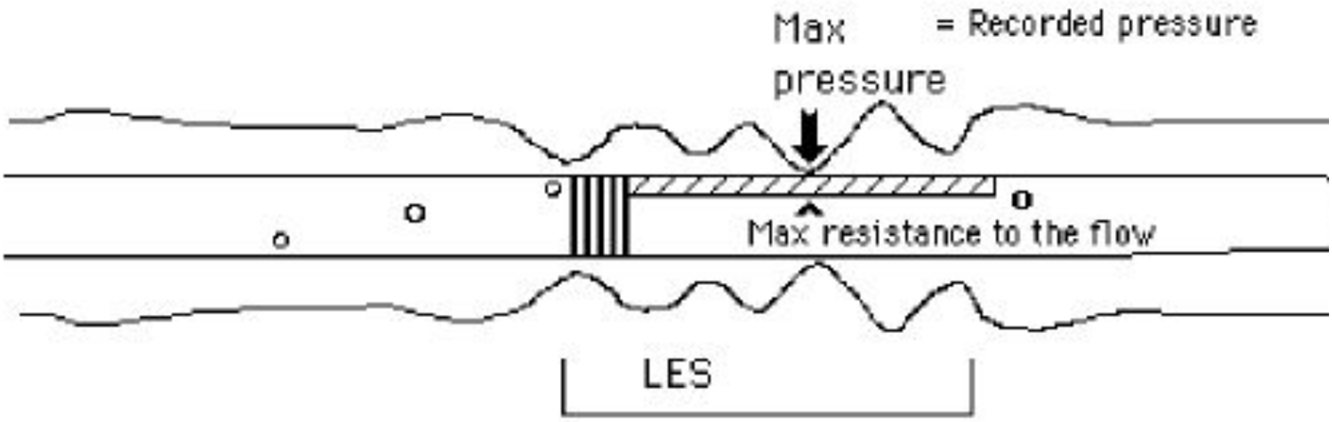



Figure 3. Dent sleeve and side holes on a motility probe.




The Dent catheter is especially useful for long-term study of the maximum resting pressure of esophageal sphincters (Figure 4), as it is not affected by small displacements of the sensor. The original description shows good correlation between the measurement of the resting LES pressure made with the side hole sensor and with the sleeve device. Another study [3] has shown a comparable resting LES pressure and significant differences in the measured duration of the LES relaxation.
A study of the normal pharyngoesophageal motility in 50 healthy subjects shows [4] that there are no significant differences in any LES peristaltic parameter between Gaeltec catheter and Dent sleeve, but that there are some differences for upper sphincter and body peristaltic parameters.

Figure 4. Principle of recording with a Dent sleeve.




We tried to compare the side hole and sleeve catheters with an experimental water chamber (Figure 5) in which pressure may vary: all two channels were perfused at 0.7ml/min by a low compliance pneumohydraulic capillary infusion pump (Arndorfer), and linked by external pressure transducers (Statham P23ID) to the Beckman R611 recorder and through the recorder, via the IRIG connexions, to an Apple Quadra 650 MacIntosh computer with a data acquisition card and a digitalization software from GWI Instruments. Pressure data were sampled at a measuring interval of 0,001 second and stored after digitalization.
The first study was the recording of a semi-rapid pressure wave with a continuous increase of the pressure at the first phase, then a continuous decrease of pressure, like in an esophageal short contraction (Figure 6): there is no significant difference between the two measured pressures. The duration of the pressure wave is a little more important with the sleeve. For rapid variations of pressure, like at the pressure inversion point, there is an average due to different values of the pressure on the 6 cm of the sleeve. Furthermore, there is an underestimation of the mean pressure (Figure 7). If the pressure variations are slower, there is a good reproducibility of the aspect of the signal, but the pressure is underestimated with the sleeve (Figure 8). For rapid waves like pharyngeal contractions, there is an important difference between the two technologies (Figure 9): pressures are significantly lower with the sleeve. Furthermore, we observed a rebound effect with negative pressures at the end of the contraction, which may be due to an overflow through the sleeve, secondary to the elasticity of the liquid chamber. This rebound effect is not observed if the pressure decrease is progressive (Figure 10).

Figure 5. Cargill's experimental system to test side hole vs sleeve.

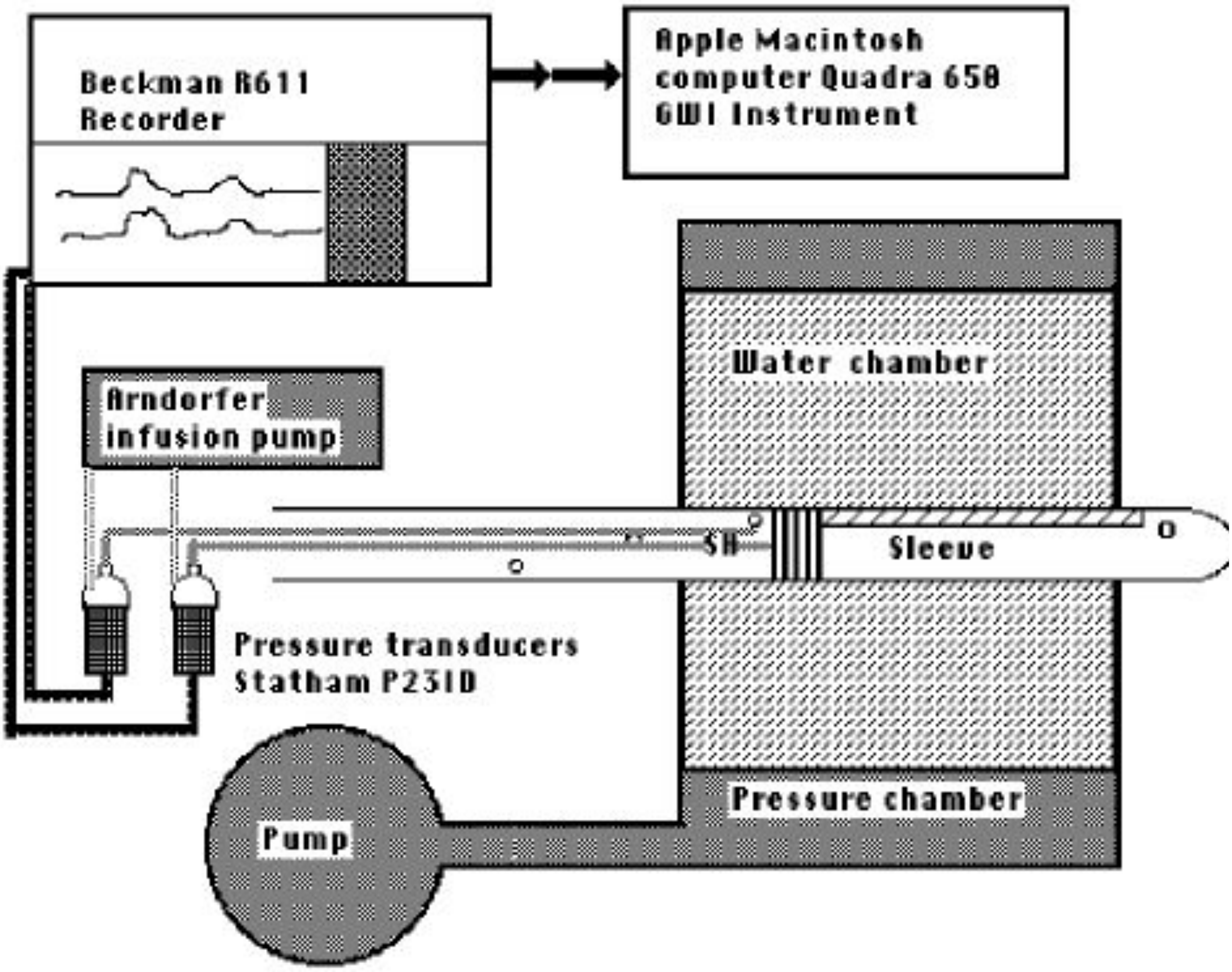


Figure 6. Comparison between side hole (in black) and sleeve (in grey) for a semi-rapid pressure wave: no difference for the pressure, but the duration of the pressure wave is a little more important with the sleeve.

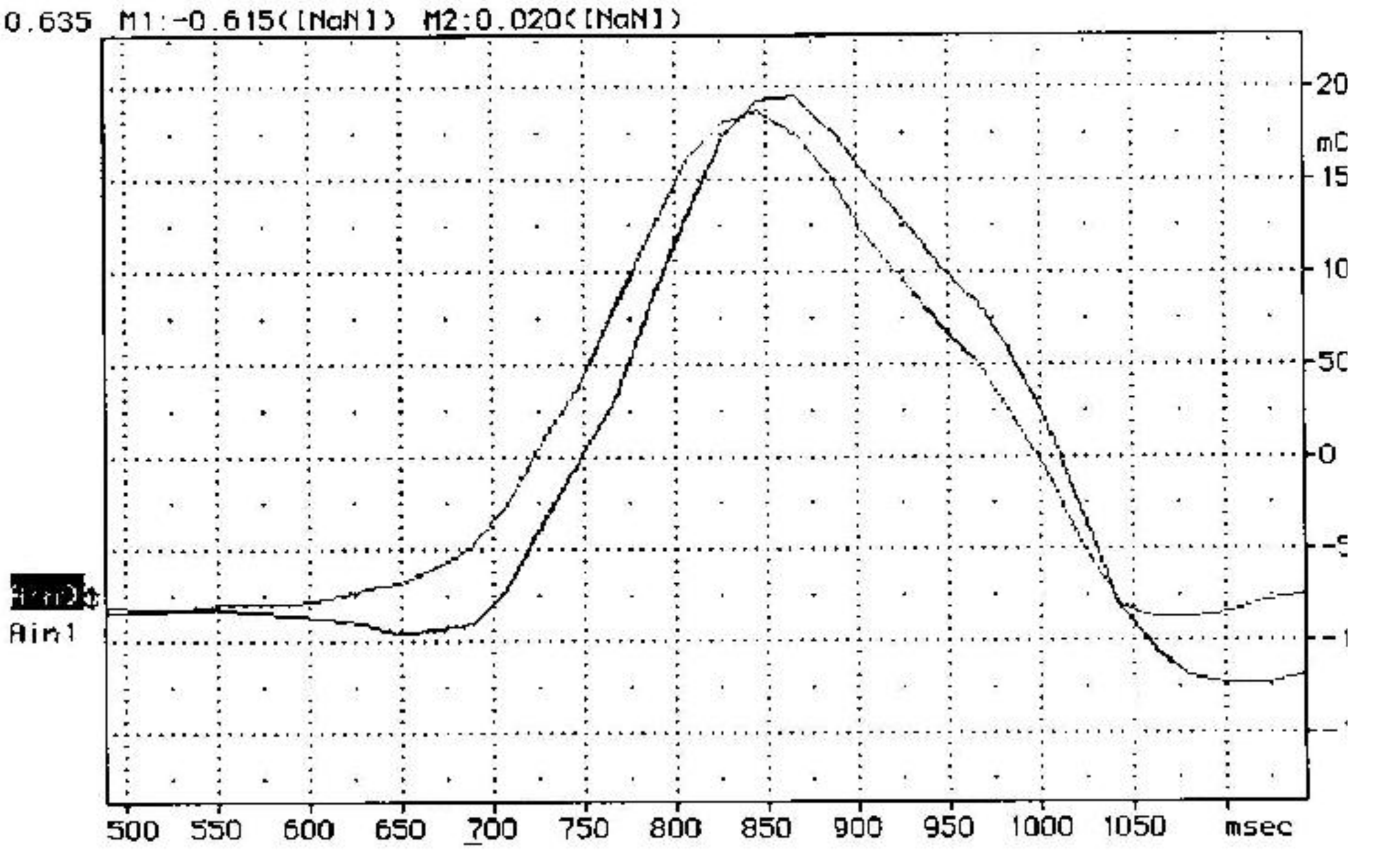
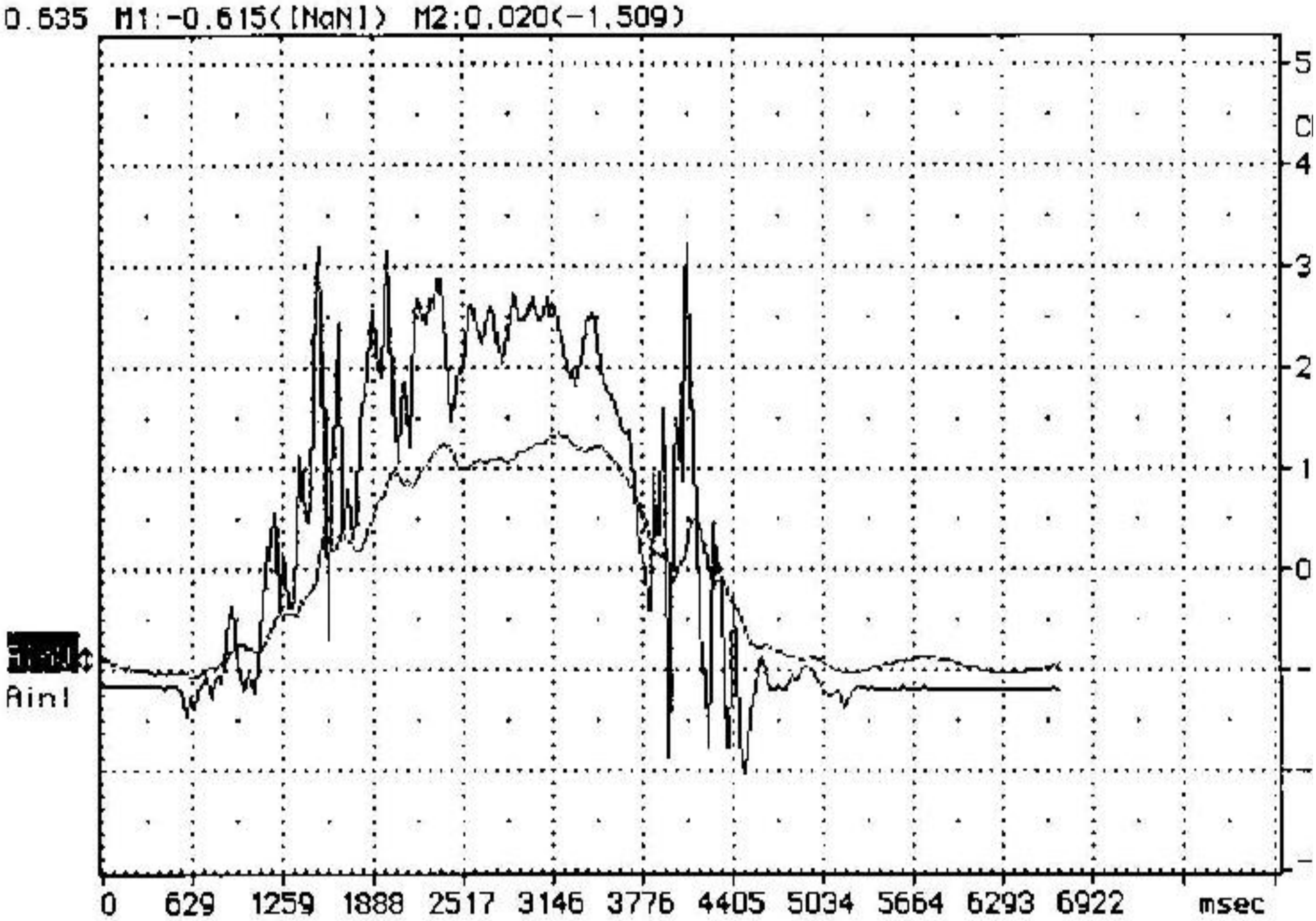


Figure 7. Comparison between side hole (in black) and sleeve (in grey) for rapid variations of pressure: there is an average of the pressure with the sleeve and an underestimation of maximum pressure.




We sometimes found some variations in relaxation study (Figure 11): an overestimation of the relaxation with the sleeve and sometimes (Figure 12) a slight underestimation. In all cases, in the first phase of the decrease of the pressure, there is an "overshoot" with a rapid and transient overestimation of the relaxation.

Figure 8. Comparison between side hole (in black) and sleeve (in grey) for semi-rapid variations of the pressure: there is a good reproducibility of the signal but an underestimation of maximum pressure.

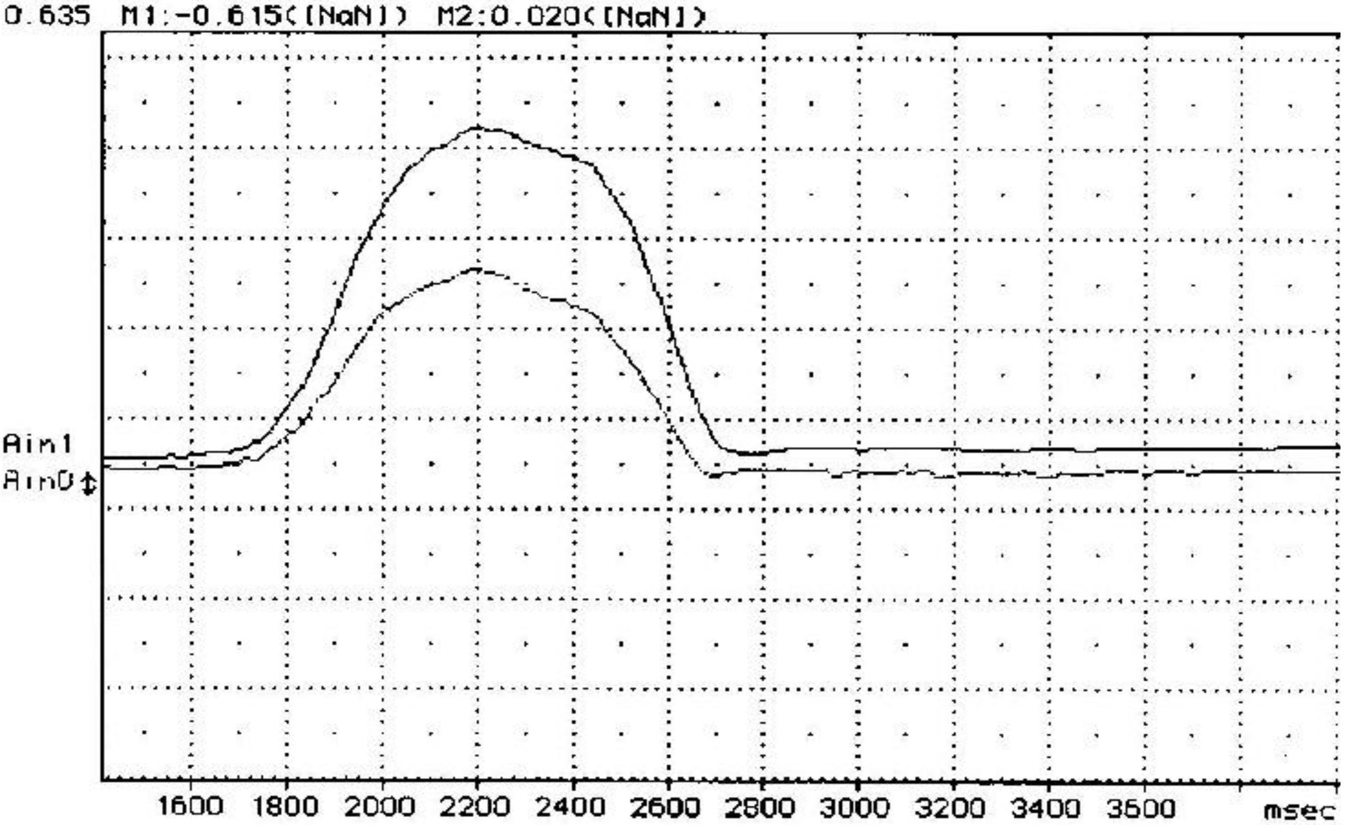



Figure 9. Comparison between side hole (in black) and sleeve (in grey) for short pressure waves like pharyngeal contractions: pressures are underestimated with the sleeve and there is a rebound effect at the end of the contraction.

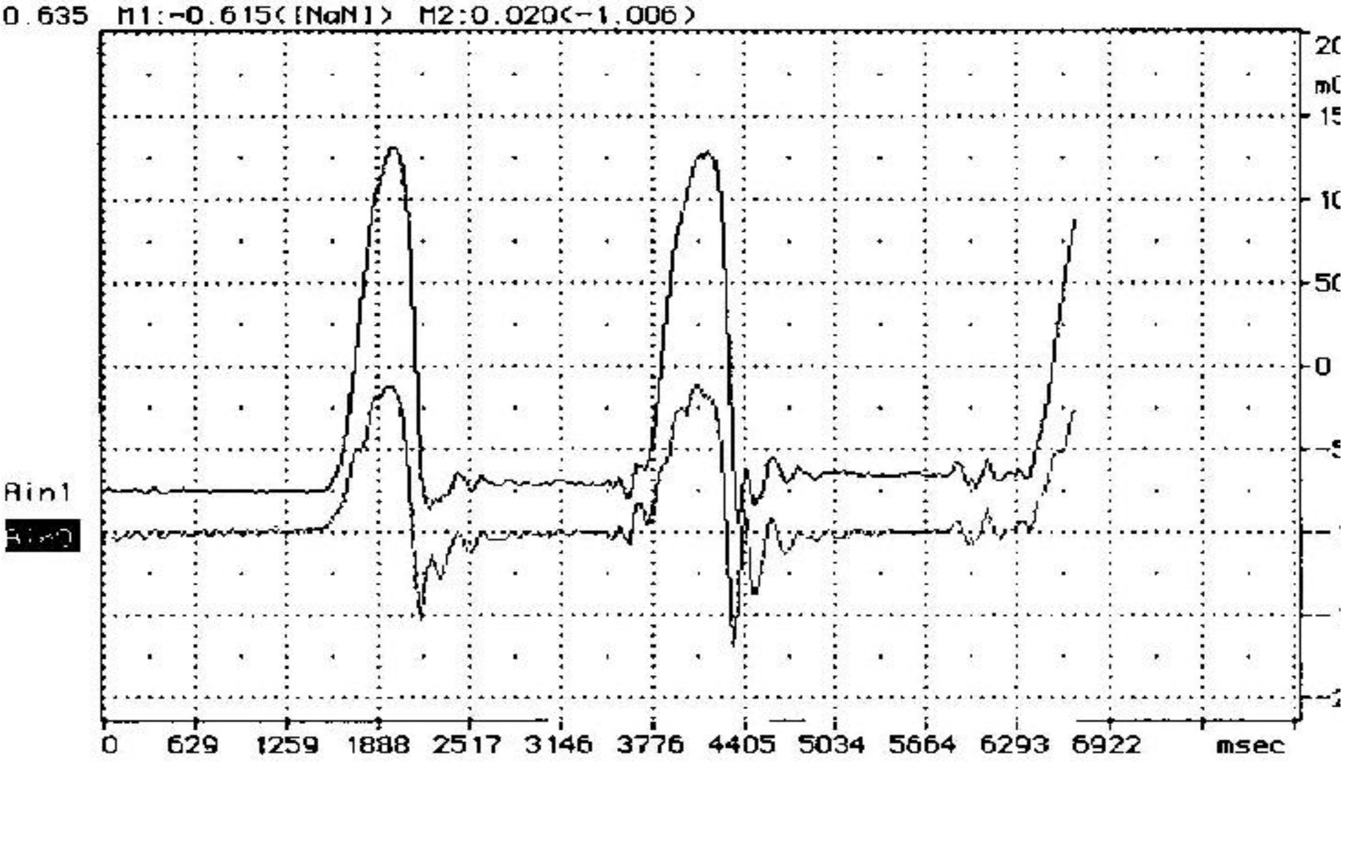


Figure 10. Comparison between side hole (in black) and sleeve (in grey) for short pressure waves like pharyngeal contractions with progressive pressure decrease without rebound effect.

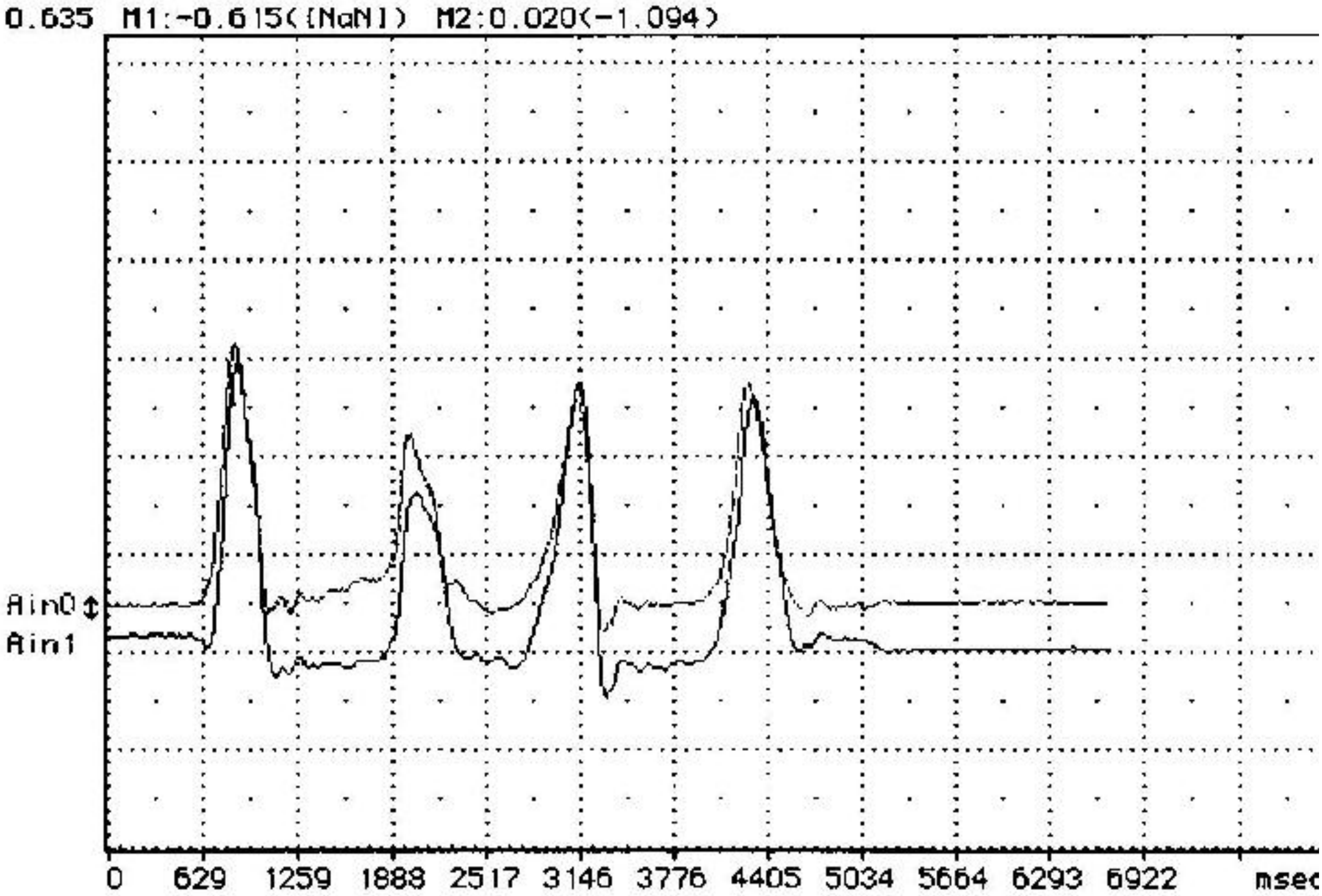



Figure 11. Comparison between side hole (in black) and sleeve (in grey) for relaxation with an "overshoot" at the first time of the relaxation and an underestimated relaxation.

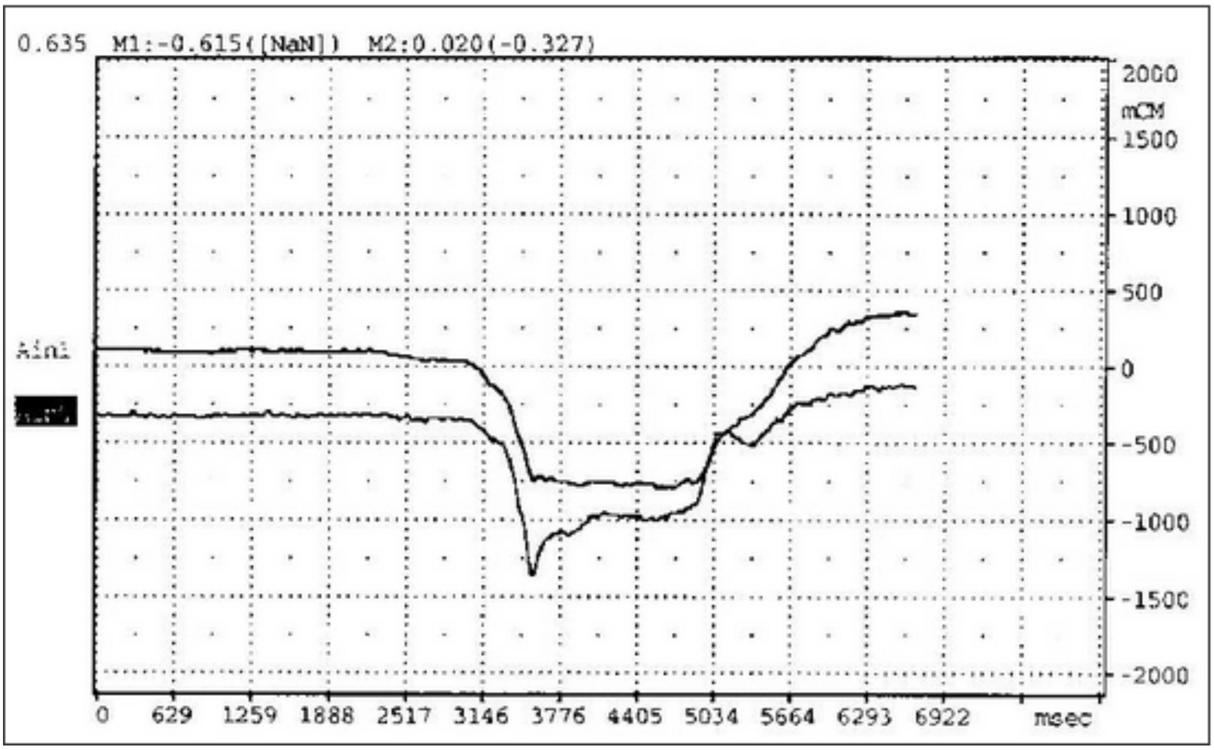
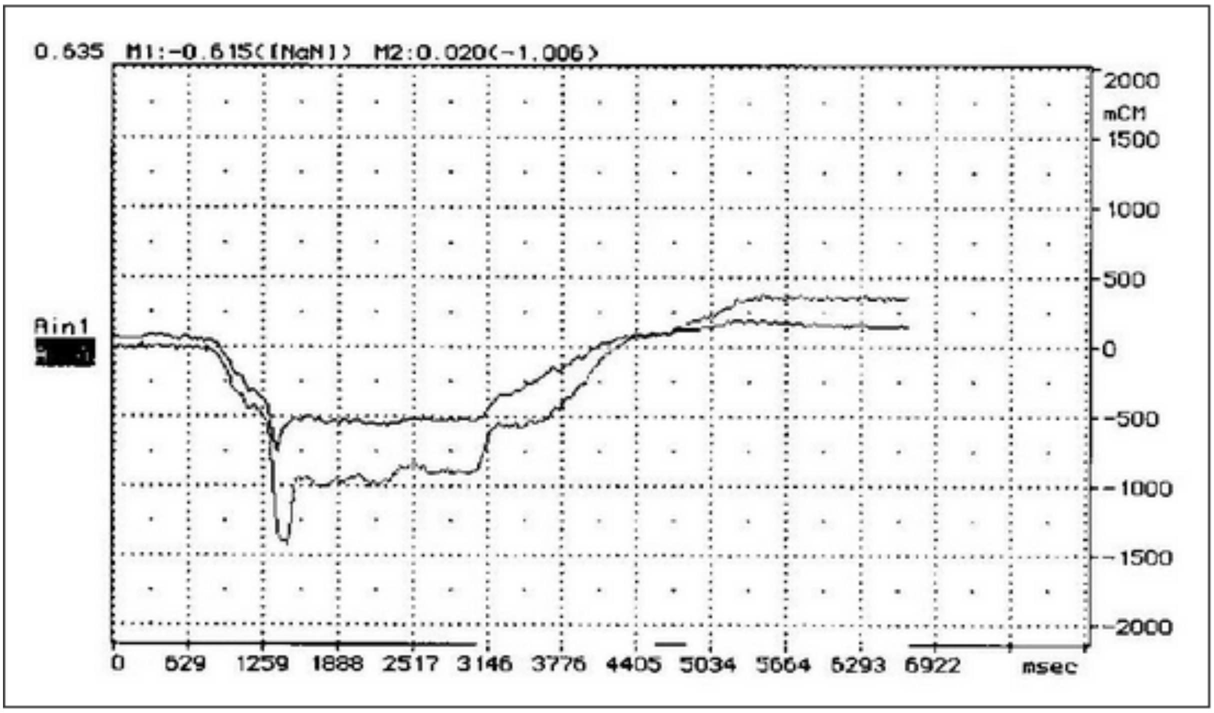


Figure 12. Comparison between side hole (in black) and sleeve (in grey) for relaxation with an "overshoot" at the first phase of the relaxation and an overestimated relaxation.




Another limit for the use of the sleeve is the asymmetry of the esophageal sphincter, the pressures being not equal in all the quadrants of the LES. With a rapid pull-through or with a station pull-through and a multilumen catheter, it is possible to study this asymmetry and to perform a LES vector volume. With a directional measure (Dent sleeve,) the asymmetry is not studied.

Conclusion

The Dent sleeve allows a prolonged study of the LES with a good evaluation of the maximum LES pressure variations, but this technique does not allow a good appreciation of rapid variations of the pressure and LES relaxation. Side hole catheters allow a better study of these parameters, but there are some limitations in their use in long-term study of the maximum resting pressure of LES, which are affected by small displacements of the sensors. Furthermore, perfused side hole catheters do not allow a correct study of very rapid variations of the pressure (UES and pharynx). Actually, the best compromise is a probe with a combination of side holes for the study of the body of the esophagus, to localize the LES, to study the LES relaxation and to perform a LES vector volume analysis, and of one sleeve for the long-term study of the LES (pharmacological tests and iterative relaxations)

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# According to the variations in lower esophageal sphincter pressure with migrating motor complex, is the conventional short-lasting withdrawal manometry technique sufficient?
# Therefore, would it be logical to carry out manometric measurements after a test meal to interrupt the migrating motor complex?

**G. Cargill (Paris)**

*Volume The Esophagogastric Junction Chapitre Anatomy-Physiology*

Between meals the small intestine, the antrum and the lower part of the esophagus exibit a recurring cycle of motor phenomena (migrating motor complex: MMC) that can be recorded electromyographically or manometrically. This consists in the sequence of a short phase of quiescence (phase 1), long phase of irregular activity (phase 2), short phase of maximum frequency of contraction (phase 3) and very short phase of resolution of the phase 3 (phase 4) followed again by a phase 1. This cycle is abruptly terminated by food but also by stress. The mean duration of a cycle is about 100 minutes (25 to 45 in newborn, 60 minutes in older children, 100 minutes in adolescents and 100 to 150 minutes in adults [1].

After meals, there is a disruption of the cycle and the activity is the same than during the phase 2 with clusters of contractions. During the phase 3 of the MMC, the sphincter tone increases. So, the manometric measurement of the sphincter competence must theoretically take into account this variation.

Nevertheless, the intubation with the manometry catheter (passage through the nostrils and the throat) is the most uncomfortable part of the entire manometric study and the stress due to this intubation is sufficient to break the cyclic activity. Therefore, for conventional short lasting withdrawal manometry technique, there is little chance that pressure variations due to MMC interfere with the measure.

Furthermore, esophageal peristalsis was initially evaluated with dry swallows, but it became apparent that afferent stimulation by wet swallows was important for reproducible and accurate quantitative assessment of the peristaltic waves [2]. Studies have traditionally been done with patients in supine position. This has been due to the limitations of water perfused systems. The increased use of intraluminal transducers and the development of long-term ambulatory pressure monitoring has promoted interest in studies in the more physiologic upright position [3, 4].

Some investigators have evaluated the effects of bolus size and composition [4, 5] and the effect of food ingestion on esophageal peristalsis [6, 7]. In case of selective dysphagia, the better way to demonstrate the presence of a disturbed activity (spastic activity) is to give to the patient the incriminated food or beverage. This practice is a supplementary reason to break the MMC.

Our laboratory routinely evaluates esophageal function during food ingestion. We feel that this represents the most natural provocative stimulus. Our technique is simply to allow the patient to eat a very small meal, naturally including the foods implicated in the apparition of the symptoms, a pharyngeal EMG allowing to know when there is a swallow. Previous studies and additional observations have indicated that patients are quite reliable in doing this. Tracings are evaluated to note whether definite abnormalities occur, such as diffuse esophageal spasm, aperistalsis, and non propagated swallows. (However, interpreting these studies is somewhat more difficult than the standard esophageal motility evaluation.) We have found this provocative test to be especially useful in unmasking motor disorders.

Conclusions

According to the variation in lower esophageal sphincter pressure with MMC, the conventional short lasting withdrawal manometry technique is sufficient because the intubation with the probe breaks the MMC. Furthermore, the administration of water or food during the examination, for the analysis of the esophageal peristaltic activity, and the research of an abnormal spastic activity, have the same effect.

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## How can the contribution of intra-abdominal pressure, crural diaphragm, and smooth muscle sphincter be distinguished in lower esophageal sphincter pressure and in lower esophageal sphincter movements?

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*Volume The Esophagogastric Junction Chapitre Anatomy-Physiology*

Manometric assessment of the lower esophageal sphincter (LES) aims to measure the resting pressure of the sphincter and to assess relaxation during swallowing. The resting pressure of the sphincter is composed of at least three components: intra-abdominal pressure, crural diaphragm pressure and smooth muscle pressure. Each of these components may vary, and the manometrical study is able to distinguish these variations.
Proper evaluation of the LES is perhaps technically the most difficult aspect of the esophageal motility study. One of the most common mistakes noted in inexperienced practicioners is the tendency to pull too quickly through the LES. In order to obtain a reliable station pull-through, this part must be done slowly, and the technician must be extremely attentive to put an end to expiratory elevations in pressure from the intragastric baseline.
Manometrical location of the position of the LES and measurement of the LES resting tone form part of every manometrical study. The location includes a study of the sphincteric and the extra-sphincteric parameters.
Therefore, the manometric study must endeavour to measure:
- the tonus of the sphincter,
- the length of the tonic zone,
- the length of the subdiaphragmatic tonic zone,
- the length of the supradiaphragmatic tonic zone,
- the distance between the orifice of insertion (in practice, the nostril) and the different structures measured as quoted here.

The study also applies to the following anatomic structures:
- the zone of the crural diaphragm,
- the esophageal hiatus.

To carry out these measurements, certain precautions are necessary:
- the use of equipment with little or no compliance,
- adequately adjusted frequency filters (lower threshold 0.3 Hz, upper threshold 30 Hz minimum),
- the use of graduated and combined probes with perfused side holes and with a sleeve.

As in every properly conducted manometric study, the probe is introduced into the stomach, where the gastric pressure is first measured. This resting gastric pressure in the expiratory phase of respiration serves as a zero reference for measurement of the LES pressure. This gastric pressure is positive, and there is an increase of this pressure with inspiration.
The probe is then withdrawn by successive withdrawals of 0.5 cm. A sufficient pause is necessary for a correct analysis of the tracing, while paying special attention to the rest pressures and the pressures during swallowing. Entry into the sphincter is identified by the increase of the amplitude of the positive gastric waves associated with respiration. This aspect seems to be more especially associated with the activity of the extrinsic sphincter, formed by the crural diaphragm and essentially by the right crus. Above this zone of exaggerated variation in pressure in inspiration, it has been observed an elevation of the basal pressure, allowing studies of relaxation in swallowing.
As the catheter is further withdrawn, a quite particular aspect is found where the variation in respiratory pressure which is imposed on the basal sphincter pressure assumes a dicrotic aspect: the effect of inspiration is followed by an increase in pressure, followed by an abrupt fall. This variation derives from the passage from the gastric zone to the thoracic zone and is associated with inspiratory depression of the diaphragm; this special point is called the pressure inversion point (PIP). Note that, below this point, the pressure is increased in inspiration due to the contraction of the abdominal wall and in particular to the depression of the dome of the diaphragm, while above this point it falls by about I KPa, due to the elevation of the rib cage and the descent of the diaphragm.

These special features simplify the location of the PIP and the sphincter, which is always situated between two consecutive tracts undergoing respiratory pressure variations in opposite directions.
Beyond the PIP, the pressures remain elevated, but vary negatively with inspiration as it has already been mentioned. The passage from the sphincter to the body of the esophagus is marked on the tracing by a fall of pressure below the gastric pressure and below the atmospheric pressure, with further depression on inspiration.
In a sphincter in situ, the highest pressure, apart from swallowing, is found a little before the PIP. It is usually advisable to record the pressure from this point, the maximum pressure occurs halfway through the respiratory variations. The values obtained over the different tracts are then averaged, so as to obtain a mean value which can be compared with the norms.
However, the following remarks are indicated:
1) when the sphincter is not in place (ascent of the sphincteric zone - hiatal hernia), the value measured before the PIP in no way reflects the mean sphincteric tonus;
2) this measurement does not allow for the fact that a very localized value does not reflect the true value of the sphincteric competence.
As the pressure increase appears to level off, the practitioner should stop the pull through and observe a stable pressure for a few seconds. At this point, the technician should request several wet swallows from the patient to assess LES relaxation.
What are the problems raised? How can the contribution of intra-abdominal pressure, crural diaphragm and smooth muscle sphincter be distinguished in LES pressure and in LES movements? The response is easy for the abdominal pressure: the positive pressure is the same in the whole abdominal cavity. The variations of this pressure are transmitted to all the organs of the cavity and to the abdominal part of the LES. Furthermore, the negative thoracic pressure creates an "aspiration" which closes the LES near the PIP. For the crural diaphragm, one of the major problem in detecting the sphincter function of the diaphragmatic hiatus has been the lack of adequate methodology. The diaphragmatic hiatus moves in an oral and aboral direction with respiration and the sensor does not move with it. Another problem is that the LES and crural diaphragm are anatomically superimposed on each other, therefore the intraluminal pressure measurement at the esophagogastric junction cannot detect whether the pressure is contributed by the LES or the crural diaphragm.
In fact there are three responses:
The first one is given by Klein [1] in a study of ten patients who had smooth muscle surgically resected for various reasons (like adenocarcinoma of the distal part of the esophagus), showing that the diaphragmatic hiatus acts like a LES with a high pressure zone at the thoracoabdominal junction in these patients, in spite of the absence of smooth LES muscle. The high pressure zone showed both tonic and phasic components. The phasic component is defined as the increase in pressure with each inspiration, as for the tonic component, described as the end expiratory pressure. This high pressure zone showed sphincterlike properties: it relaxed in response to a proximal stimulus (swallowing with an inhibition reflex of the inspiration) and contracted in response to a distal stimulus (increased intra-abdominal pressure). Boyle [2] does not find any evidence of the contribution of the crural diaphragm to the end expiratory esophagogastric junction pressure with the use of pancuronium to paralyze skeletal muscle of the crural diaphragm. In this very important study, there is a surgical manipulation of the esophagogastric region with a possible stenosed diaphragmatic hiatus.
The second answer is the attentive manometric study of patients with LES malposition (hiatal hernia). In these cases, the smooth muscle region slips off the crural diaphragm zone to the thoracic zone and it is possible to study the action of the external LES with the same findings as Klein. But in some cases, there is some difficulty because there is neither phasic zone (dilation of the hiatus, no action of the crus on the LES) nor tonic zone with an end expiratory pressure equal to the gastric pressure. All these abormalities must be described in the report as a deficit of the external sphincter. In our experience with these cases (see Figure 1), the external sphincter essentially generates a phasic activity and sometimes a little tonic activity. This phasic activity is easily found in the lower part of the sphincter in a patient without malposition. The appreciation of this activity allows to have an idea on the competence of the external sphincter.
The third response is given by studies with an association of a manometric study with a sleeve and a simultaneous measurement of the crural diaphragm electromyogram which indicates the origin of the pressure variations, but such studies are not common. In the awakened normal humans, indirect evidence through EMG recordings shows either absent or very little contribution of the crural diaphragm to the end expiratory pressure in the resting periods [3].

The contribution of the smooth muscle in standard manometry must be appreciated with the measurement of the surpradiaphragmatic pressure. At this location, there is no action of the external sphincter. Under the hiatus, it will be most difficult.

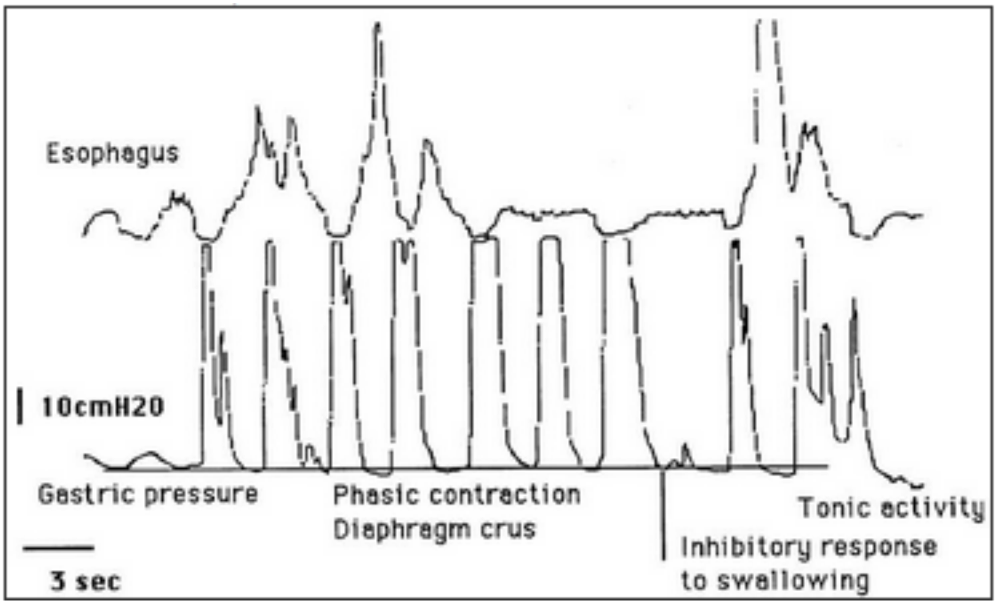

Figure 1. Phasic activity in the lower part of the LES.

Conclusion

In a standard manometry it will be possible to have an idea of the contribution of the intra-abdominal pressure, crural diaphragm and smooth muscle on the competence of the LES. This requires a very attentive study of the resting pressure zone, a very slow pull through, a complete study of the position of the sphincter in comparison with the hiatus, and requires, also, a specific technology. The measurement of the abdominal pressure is the first phase of the manometric examination. This pressure is common to all the abdominal cavity which mimics a liquid cavity, and the variations are quite equal in all the organs of this cavity. The action of the crural diaphragm (right crus) is essentially a phasic activity in the lower part of the pressure zone, and the smooth muscle activity is essentially responsible for the tonic activity. The exact contribution of each component is not yet determined.

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## What is the incidence of transient disorders ?

**G. Cargill (Paris)**

*Volume Primary Motility Disorders of the Esophagus Chapitre Common problems*

Before dealing with transient disorders, we should make clear here what is understood by this term. It is essential to distinguish these disorders from episodic disorders, such as the spasms induced by reflux. In this latter case the disorders are repetitive in time, each episode being separated from the previous one by a variable period. In our view, transient disorders which occur over a particular and usually short period and are not repetitive.
The problem of transient disorders is one that is difficult to discuss and to resolve. It may well be possible to exhibit transient esophageal disorders, but these anomalies are not often investigated, manometric investigation is mostly in request for the study of chronic disorders which have often already been investigated endoscopically and radiologically without these examinations or symptomatic treatment putting an end to the symptoms. Thus, the indications for manometric examination, as most often performed by us in adults, are as follows:
gastroesophageal reflux resistant to treatment (preoperative assessment);
- dysphagia;

- pseudoanginal pain ;
- assessment of various anomalies: collagenoses;
diabetic or other neuropathies ; neurologic lesions.
In most cases, the investigation of such patients demonstrates anomalies related to the clinical disorders.
The only transient disorders of the adult that we have had the opportunity to see corresponded to:
odynophagia associated with a viral or bacterial esophagitis with diffuse, nonspecific and regressive motor disorders.
- rare cases of burns due to physical agents (very hot liquids or soups) or chemical substances;
- iatrogenic motor anomalies associated with agents decreasing motility (such as calcium antagonists) or increasing it (bethanechol).
We should also include in this section the exogenoses, such as tobacco and alcohol abuse.
It is necessary to distinguish from these rare disorders the episodic disorders of motility, such as those of spasmodic type, which are not detected at basic examination but which occur during provocation tests (except for false-positives).
Otherwise, our control population consisting of 60 clinically healthy students studied during various pharmacologic schedules exhibited no major anomalies, apart from some polyphasic waves the incidence of which has been reported as 11 to 18 p. cent by Richter [1].
Transient disorders seem to be commoner in children, since we have often found partial achalasia accompanied by reflux as well as sphincters of variable tonus with associated partial achalasia and esophageal spasm. These anomalies are often found in children suffering from indisposition, sometimes serious, and are sometimes accompanied by disordered vagal regulation (bradycardia, apnea, etc.), so that they seem to form part of a process of disturbed maturation of the autonomic system. This is, as it were, a transient dysautonomy. The same applies to the sphincteric anomalies sometimes seen in the newborn, a hypotonus which disappears at the age of a few weeks.

Conclusions
If we distinguish transient disorders and episodic disorders detected during repeated examinations by provocation tests, it does not seem that the incidence of transient disorders is very considerable in the adult, though there may exist iatrogenic disorders (in which tobacco and alcohol abuse may be included) or disorders secondary to transient affections (infective esophagitis, burns, etc.). On the other hand, such disorders are much commoner in children because of postnatal maturation of the sphincter and disorders of autonomic maturation. However, it is difficult to define the incidence of such disorders for obvious ethical reasons.

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## What are the manometric findings observed during the painful crises and at other times ?

**G. Cargill (Paris)**
*Volume Primary Motility Disorders of the Esophagus Chapitre Pseudoanginal pains of esophageal origin*

Disorders of esophageal motility are involved in the genesis of pseudoanginal pain, but disorders of esophageal microperfusion are also suspected as being the source of the motor disorders during swallowing [1]. In making a proper study of the esophagus in this context, it is initially essential to exclude a cardiac condition which may directly threaten the patient's life. However, one must be aware that the investigation of certain disorders (syndrome X, disorders of microperfusion) is neither clearly defined nor sure. Therefore, before performing a manometric study and provocation tests, it is necessary to exclude, as far as possible, a cardiac source of the symptoms by a complete investigation including coronary arteriography and scintigraphy.
The manometric study is aimed, not only at demonstrating disorders known to be possible causes of pain (by excitation of the esophageal mechanoreceptors and chemoreceptors), but also, in order to confirm the responsibility of the esophagus in this pathology, at demonstrating the direct relationship between a disorder of esophageal motility and the pain. In fact, the incidence of esophageal and of cardiovascular disorders increases

with age, and they may coexist in a given patient. Hence, there occur a certain number of problems associated with the fact that the esophageal pain is random and that the investigation may be conducted at times other than these sometimes brief periods. There are two possible solutions for analysis of these disorders: the first is long-term 24-h recording of the disorders by ambulatory analysis. However, such a study may be made during a pain-free period, as the patient may not exhibit the least painful crisis during the 24 hours of observation. In our limited experience of this type of examination (22 ambulatory tests), only 4 patients (18 %) developed pain during the examination.

The second solution, which also provides the reply to the objections made to the first, consists of manometric testing to see whether the crises can or cannot be precipitated by pharmacologic methods.

These tests are numerous, as follows : - Bernstein's test, or the perfusion test, consists of perfusing 0.1N HC1 into the esophagus. Such perfusion can be made independently of manometry, or, as we prefer, during manometry, via a catheter placed in the upper part of the body of the esophagus, the manometric recording being made simultaneously in the lower part of the esophagus by other catheters in the sound. This way of performing the test makes it possible to distinguish pain associated with the action of acid on the esophageal mucosa from pain associated with spasm (itself induced by acid perfusion).

The edrophonium test is intended to reinforce esophageal contractility by intravenous injection of an inhibitor of acetylcholine esterase, and has replaced the ergonovine test (see below), which is not devoid of risk. We may note in passing that even edrophonium test is not completely free from risk in cases of cardiac arhythmias, and that it requires both cardiac monitoring and a venous line as well as the possibility of immediate administration of atropine to the patient in the event of bradycardia or malaise.

Esophageal distension by means of a balloon (or air) consist of inflating a balloon in the esophagus or the rapid dispatch of a bolus of air to the upper part of its middle third. This is a useful test because it is sensitive, rapid to perform, and devoid of dangerous consequences.

Alkalinization is capable of modifying the motor profile of the esophagus [2]. In our hands, this test consists of giving an alkaline loading-dose intravenously, followed by a period of hyperventilation, with monitoring of the blood-gases by the capillary route. This is a long test, relatively burdensome for the patient, which calls for cardiovascular monitoring, a venous approach, and sampling for determination of blood-gases. Despite these limitations, we have had no special problems with this test in our series. The ergonovine tartrate test is the manometric equivalent of the test performed during coronary arteriography and aimed at precipitating coronary spasm. Though the half-life of the agent is short, this test is not altogether devoid of risk, and delayed spasms may be observed ; it has therefore been replaced by the Tensilon ® (edrophonium) test described above. This implies that it should be performed after a preceding test, usually made during coronary arteriography, in a monitored patient with a venous line in immediate proximity to a cardiologic unit capable of taking responsibility for the patient. It also implies prolonged surveillance subsequent to the test. In our own experience, during such tests performed under the conditions described above, we have observed major modifications of the ECG occurring concomitantly with anginal pain and without specific esophageal abnormalities. Despite the immediate administration of trinitrine i.v., the ECG changes persisted for several hours though without giving rise to infarction.

These tests may be performed independently during a manometric examination or, as is our usual practice, grouped together, as when an alkalinization test is followed by a Bernstein test, which in turn is followed by an edrophonium test and then by an air test. This procedure permits increased sensitivity of the manometric test, which individually have variable and often poor sensitivities, and remains well tolerated by the patient.

We conduct the test in the following order:

1) Bernstein test 4 ml/min — 20 min.
2) Injection of edrophonium at 18 min.
3) Performance of balloon test 3 min after injection.

As the anomalies sought are transitory, it is logical to think that the motor disorders sought may also be transitory. Moreover, any particular disorder may not be painful whenever it occurs. Thus, if reflux is involved, this is not necessarily accompanied by pain at each fall in pH. It seems clear that the pain results from the conjunction of a precipitating factor and a particular state of receptivity.

In view of their great diversity, it is difficult to review exhaustively here the totality of the disorders that may be observed, either spontaneously or during provocation tests, but a listing of the disorders by group or cause may be attempted, as we have tried to do below.

Disorders associated with reflux

Reflux is not detected as such by manometry, but by measurement of pH. However, the ascent of acid gastric chyme into the body of the esophagus may induce an inappropriate motor response capable of giving rise to the pain.

Globally, in this situation, the baseline anomalies observed are those associated with the reflux (hypotonia and/or malposition to the LES, moderate nonspecific dyskinesia in proportion to the reflux), which may be minor or even absent.

In this situation, Bernstein's test may produce pain, possibly without associated hypercontractility (pain associated with reflux), but often with various motor disorders of the type of tertiary contractility and/or more or less polyphasic non-propagated waves. This pain, unaccompanied by abnormal spasm, is the result of excitation of the parietal nociceptors by the reflux of acid chyme. During ambulatory coupled manometric and pH studies over 24 hours, this corresponds to pain without esophageal spasm during an isolated reflux.
In other cases, acid perfusion is capable of provoking an esophageal hypercontractility with the development of various spasmodic disorders of the type of either diffuse spasm or of nutcracker esophagus, but pathologies of the type of isolated spasms are equally possible. These anomalies may or may not be accompanied by pain. Only the occurrence of pain simultaneous with the motor disturbance allows a formal connexion of the two abnormalities. In other cases, the responsibility of the esophagus may be suspected without actually being confirmed. On this hypothesis, the esophageal nociceptors and baroreceptors are responsible for the pain. During coupled manometry and pH measurement over 24 hours, this is evidenced by reflux accompanied by the abnormal spasm and pain.
The air test (rapid injection of air into the upper esophagus or balloon inflation) is also often positive in this population where a certain hypersensitivity may be suspected within the context of intestinal irritability. This test may give rise to spasm accompanied by pain, which occurs during the test. If the basal motility is normal or subnormal, or only moderately disturbed, this is suggestive of reflux.
Achalasia
Mega-esophagus is a pathology equally well-known as capable of producing anginal pain. Observations under baseline conditions show disturbed relaxation of the lower sphincter, a sometimes elevated sphincteric tonus, inversion of the gastroesophageal pressure gradient, as well as a very suggestive dyskinesia consisting of repetitive, non-propagated, dome-shaped waves. The basal presence of such an anomaly may arouse suspicion of the esophageal origin of the pain, but we have sometimes been able to reproduce it by means of the amyl nitrite test. This test consists of making the patient inhale the content of an ampoule of amyl nitrite, and in cases of idiopathic mega-esophagus it provokes a reaction in two stages:
a) in the first stage, there is observed a transient disappearance of the tonus of the lower sphincter (and of esophageal motility), often accompanied by some degree of restoration of the gastroesophageal gradient. Also, to some extent, this total abolition of sphincteric obstruction allows distinction between idiopathic mega-esophagus and mega-esophagus secondary to tumoral pathology.
b) following this period, the sphincteric tonus reappears with a marked increase in sphincter pressure and with sometimes spasmodic esophageal waves of markedly increased amplitude and duration. Constrictive pain is then common, either in the phase of frank hypertonus of the LES or during some of the spasmodic contractions occurring during this phase of hyperreactivity.
Anomalies of esophageal contraction other than in reflux or achalasia
These are not always permanent, which doubtless also explains why these disorders are inconstant. Sometimes the appearance of diffuse spasm, nutcracker esophagus or isolated spasm is evoked only by stimulation. The appearances of nutcracker esophagus can also be found under basal conditions without concomitant pain. Stimulation by edrophonium [3] or by alkalosis, which is more physiologic, may enhance the intensity of the disorders and evoke simultaneous pain.
Incidence of spontaneous and provoked disorders : some data
In a personal series [2] of 33 patients (14 men and 19 women with a mean age of 51.7 years), basal manometry demonstrated only 8 (24%) primary motor disorders, of which 2 were nutcracker esophagus, 3 mega-esophagus and 3 diffuse spasm of the esophagus. In the other 25 patients, the alkalosis test gave rise to pain correlated with a tonic anomaly of the LES or giant waves in 5 cases (15.1 % of the total series or 20 % of the subseries), while motor disorders unaccompanied by pain developed in 9 supplementary cases (36 %). Overall in this series, a probable esophageal source of the pain was suggested in 39 p. cent of cases but proven in only 15 p. cent (2 attacks during the test in the first 8 patients and 3 in the other 25). Among the 910 patients reported by Richter [3], only 255 had disorders of esophageal motility. (28 %). The nutcracker esophagus constituted 48 p. cent of these
anomalies, diffuse spasm 10 p. cent, non-specific motor disorders 36 p. cent, hypertonus of the sphincter 4 p. cent and achalasia 2 p. cent. In this series, Bernstein's test reproduced the patient's pain in 61 cases (7%), as did the edrophonium test in 210 cases (23 %). In all, 27 p. cent of the patients had the pain reproduced by such tests and were confirmed as certainly having pain of esophageal origin.
Like the preceding report, numerous other publications give the nutcracker esophagus as being the most commonly found motor disorder in the investigation of such patients.

**Conclusion**
Investigation of patients exhibiting pseudoanginal pain with a normal coronary arteriogram relies on provocation tests. In practice, motor esophageal disorders are not constant, and it is useful to modify the basal motility in order to certainly connect both types of anomalies. Apart from reflux (studied by pH measurement) these

disorders may be associated with different motor disorders, the commonest of which is the nutcracker esophagus. It is essential that the motor disorder in question be accompanied by pain if responsibility of the esophagus is to be assumed. Some of these disorders may occur without any pain at times other than the painful crises.

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## What is the proportion of dyskinesia related to esophagitis ?

N. Boige, F. Viarme, **G. Cargill**, J. Navarro (Paris)
*Volume Primary Motility Disorders of the Esophagus Chapitre Infants and Children*

Dyskinesia secondary to an esophagitis is frequently seen in infancy, given the raised incidence of gastroesophageal reflux (GER) at this period of life. There exists in the child a dyskinesia associated with the esophagitis itself, as shown by Cucchiara [1], and disappearing with the treatment and cure of the esophagitis. However, in many pediatric cases, the anomalies of motor function linked with the esophageal inflammation are mingled with the motor anomalies causing the reflux, or with other anomalies due to the fact that maturation of esophageal motility is still incomplete.
The dyskinesia associated with esophagitis is manifested in the body of the esophagus under differing, but often associated, aspects. Anomalies of primary peristalsis are observed and render it inefficient: « absent» primary peristalsis, evidenced by absence of the primary wave following deglutition or by disappearance of the primary wave in mid-trajectory in the body of the esophagus (non-transmitted wave); « incomplete » primary peristalsis, the primary wave ending in the lower third
of the esophagus as a shower of waves of abnormal structure and amplitude less than normal, often simultaneous and non-propulsive; a transmitted primary peristaltic wave which is not propagated or is abnormally structured: too wide, with decreased amplitude, deviant or polyphasic, the amplitude decreasing during progress of the wave unlike the normal appearance of decrease of amplitude opposite the aortic arch followed by increase during progress towards the cardia. Impairment of the speed of propagation may be apparent (propagation slower than normal).
To these anomalies of primary peristalsis are frequently added « irritative »tertiary waves, which are dome-shaped and polyphasic. It is an important fact that these anomalies predominate in the lower third of the esophagus in cases of moderate esophagitis affecting the lower esophagus, the commonest case, but they involve the entire body of the esophagus in severe extensive forms of peptic esophagitis. They are not accompanied by esophageal stasis, the esophago-gastric pressure gradient usually remaining unaffected ; in rare cases, there is equalization of the esophageal and gastric pressures. On the other hand, in cases of commencing peptic stricture, an increase in basal esophageal pressure is found opposite to the stricture, with conflicting waves proximally.
These anomalies of the primary waves and the presence of tertiary waves are regarded as pathologic if they reach a percentage above or equal to 20 p. cent of the primary waves.
In fact, primary peristalsis is installed in the normal child and effective from birth, after maturation occurring between 35 and 41 weeks of gestation.
Manometric anomalies may exist before esophagitis visible macroscopically at fiberoscopy, but they usually coexist with histologic lesions of esophagitis if biopsies are made. The motor anomalies are correlated with the severity of the esophagitis and constitute a true vicious circle, since they impair peristalsis and therefore acid clearance of the esophagus and prolong the period of acid attack on the mucosa during episodes of reflux.
The mechanism of this dyskinesia may be the local liberation of mediators of inflammation such as the prostaglandins, or an indirect effect of the acid aggression on the submucosal esophageal nerve plexuses.
At the lower esophageal sphincter (LES) level, the dyskinesia of the reflux esophagitis is often accompanied by « repetitive » or « inappropriate » relaxations occurring unrelated to deglutition. The repetitive relaxations are

more often involved in reflux episodes in infants with GER and esophagitis (67 % as against 32 % in the experience of Cucchiara et al.) than in infants with GER but without esophagitis.
According to many authors, the inappropriate relaxations constitute the chief mechanism of reflux in children, well ahead of other conditions: the classic triad of hypotension, malposition and shortness of the LES, appropriate relaxations of the LES, and increases of intragastric pressure [2, 3,4]. Certain repetitive relaxations may be associated with the esophagitis itself, constituting a reflex reaction to acid aggression, which would explain their increased incidence in cases of esophagitis, but they are also causal.
The repetitive relaxations may coexist in children having GER, either with periods of normal tonus and function of the LES, or with hypotension of the sphincter, or with other anomalies of sphincter function indicative of immaturity of esophageal motility, i.e., appearances of hypertension of the LES of varying duration with partial achalasia during deglutition.
At the upper esophageal sphincter (UES) level, the dyskinesia of esophagitis is accompanied, either by a hypertension reactive to the acid aggression which protects the rhinopharynx, laryngeal apparatus and respiratory tract against reflux, or a pharyngo-sphincteric asynchronism, indicative of a reflex disorganization linked to the acid reflux or of an incoordination due to functional immaturity, sometimes of a hypotension which allows reflux of the acid content as far as the rhinopharynx and larynx, producing respiratory or otorhinolaryngologic complications.
The manometric confirmation of a dyskinesia of major esophagitis associated with inappropriate relaxation of the LES has therapeutic implications: it necessitates recourse to powerful prokinetics such as bethanechol, which improves esophageal clearance by increasing the amplitude of primary peristalsis and decreasing the speed of propagation of the wave in the lower esophagus.
It also justifies specific treatment of the esophagitis, which may need to include the use of antisecretory agents in order to break the vicious circle. On the other hand, there is no treatment dealing with the repetitive relaxations and other anomalies of maturation of function of the LES.

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## What is the proportion of primary esophageal disorders in the infant ?

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*Volume Primary Motility Disorders of the Esophagus Chapitre Infants and Children*

The primary dyskinesias of the esophagus in childhood in the absence of any reflux [ 1 ] pathology are seen in cases of anomalies of maturation of esophageal motility, malformations of the esophagus (esophageal atresia) and the rare cases of extensive alimentary dysmotility (chronic pseudo-obstruction of the intestines).
Partial achalasia of the lower esophageal sphincter
Certain motor anomalies are particularly associated with the first months of life, and may or may not be related to varying degrees of anomalous motility of the lower esophageal sphincter (LES), the body of the esophagus and the upper esophageal sphincter (UES). There exist phenomena of partial achalasia of the LES in intermittent or constant swallowing, the LES otherwise having normal tonus or hypertension and a normal position.
These phenomena of partial achalasia may alternate with episodes of normal or inappropriate relaxation. The body of the esophagus may be associated with a dyskinesia consisting of non-propagated waves, or of simultaneous large and high-amplitude spasmodic waves at several levels. The upper sphincter is frequently the site of a pharyngo-sphincteric asynchronism. Despite the partial achalasia, there is no obstructive esophageal symptomatology, at most equalization of the esophageal and gastric pressures.

These motor anomalies may be discovered during an examination instigated by clinical signs compelling investigation for gastroesophageal reflux [1] (vomiting, throwing-up, recurrent pneumopathies), but especially and with particular frequency in infants who have suffered severe malaise. This anomaly of esophageal function often coexists with cardiac signs of vagal hyperreactivity, where the esophageal dysfunction may be an alimentary site of the vagal hypertonus.

As for the origin of these disorders, the hypothesis propounded is the existence of delayed maturation of esophageal motility, based on the alternation with other anomalies of LES function which frequently result in pathologic reflux such as recurrent relaxations, confirming the variability of the anomalies with time and the usually transitory nature of the anomalies.

These partial achalasias of childhood [2] pose a tricky therapeutic problem: in practice, it is desirable to improve the relaxation of the LES and the dyskinesia of the body of the esophagus without aggravating the gastroesophageal reflux (GER). Moreover, the coexistence of GER and vagal cardiac hyperreactivity evokes the risk of serious illness and even the sudden death of the infant.

Esophageal atresia

The anomalies of esophageal motility are particularly severe in the context of esophageal atresia [3].

In fact, in all the published series, infants operated for atresia have postoperatively - even in the absence of anastomotic tension — a major GER associated with malposition and hypotension of the LES and an esophageal clearance of very poor quality due to dyskinesia of the body of the esophagus. This is most marked at the level of the anastomosis, with disturbed transmission of the waves from the striated to the smooth esophagus, and it is considerable in the lower part of the esophagus distal to the anastomosis, where there are low-amplitude, non-propagated waves (90 p. cent of cases in our series). In the upper esophagus, motor function is usually normal.

The dyskinesia of the lower esophagus is not correlated with the severity of the reflux, but seems linked with the esophageal malformation, due perhaps to anomalies of the intramural plexuses. It predisposes to a risk of severe esophagitis and even of peptic stricture, and often necessitates a secondary antireflux procedure (30 p. cent in our series), the postoperative success of which may be impaired by persistent dyskinesia of the lower esophagus.

The esophagus and chronic intestinal pseudo-obstruction

Particular anomalies of esophageal motility are observed in extensive disorders of alimentary motor function : chronic intestinal pseudo-obstructions [4] due to alimentary neuropathies or myopathies. In the digestive neuropathies, the dyskinesia is situated in the body of the esophagus with broad and tall primary waves of short duration, usually non-propagated and simultaneous, whereas in our pediatric series the LES had a normal or low tonus and a usually normal motility.

The UES is frequently the site of an asynchronism. In the digestive myopathies, there is a very clear-cut difference between the subnormal motility of the upper striated esophagus and the much impaired motility of the smooth esophagus, where the waves have domes of very low amplitude and are not propagated.

Other primary dyskinesias

Finally, certain primary dyskinesias analogous to adult pathologies may have their onset in childhood.

Idiopathic achalasia or mega-esophagus may be observed from the first decade, with the same manometric signs (hypertension of the LES, absence of relaxation in swallowing, conflicting waves and esophageal stasis, then hypokinesia) and the same course as in the adult: initially, reversibility of the LES anomalies by amyl-nitrite, then progressive resistance to medical treatment and a need for dilatation or surgical intervention. The achalasia may form part of the picture of a more general autonomic dysfunction [5], or of a syndromatic picture (achalasia, alacrimia, glucocorticoid deficiency).

Rare cases of isolated esophageal spasm have been observed in children.

Just as in adults, general disorders such as scleroderma may be ushered in by esophageal motor disturbances in children.

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# Is there a correlation with manometric achalasia ?

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*Volume Primary Motility Disorders of the Esophagus Chapitre Idiopathic motor disorders of the esophagus in the elderly*

The contribution of manometric technologies and their present improvements would be only of physiologic interest if disorders of swallowing were not so common in the elderly. These are a source of both functional handicap and of malnutrition [1].
These disorders may be associated with a functional anomaly of the upper part of the esophagus and the oropharynx, but also, more rarely, with motor disorders of the body of the esophagus and of the lower sphincter. Oropharyngeal dysphagia may be associated with numerous causes of complex mechanism, listed in table I. Some of these may be found in the infant and child (and are not included in the present context), while others are more specific to the elderly subject. Manometric study may be a decisive factor in the diagnosis of some of these disorders, as is the case in scleroderma, but more often provides guidance and understanding in locating the physiopathologic origin of the disorder, either in the pharyngo-sphincteric region alone, or as a disorder affecting the whole of esophageal motility.
In the oropharyngeal region, the disorders found may be listed as a certain number of motor entities in terms of the anomalies found at manometric

Table 1. Neuromuscular causes of oropharyngeal dysphagia (after Green [1].) (Those italicized are the commonest disorders of the elderly).

Central nervous system

Cerebral vascular accident with bulbar involvement or pseudobulbar paralysis. Parkinson 's disease. Multiple sclerosis, amyc
lateral sclerosis, syringobulbia. Stiff-man syndrome, brain-stem tumor, Duchenne's disease, Riley-Day syndrome or dysautoı
stem lesions associated with parturition, neonatal bulbar lesions, « immaturity » of the brain-stem.

Peripheral nervous system

Mononeuritis, neuropathies (diabetic, alcoholic, diphtheritic, tetanus, botulism, etc.)

Motor endplate — neurotransmission

Myasthenia

Muscle

Myotonic dystrophy, oculopharyngeal muscular dystrophy, polymyositis and dermatomyositis, metabolic myopathies

examination. These anomalies (table 2) are of several types: those involving only sphincter pathology, and those concerning anomalies above the sphincter (and possibly associated with the foregoing).
Clinically, functional disorders of the upper esophageal sphincter (UES) are associated with dysphagia essentially for fluids, regurgitation and the sensation of a lump in the throat.

Table 2. Motor causes of oropharyngeal dysphagia : motor disorders found.

Hypertonus of upper sphincter

Hypotonus of upper sphincter

Anomalies of relaxation :

Achalasia or incomplete relaxation, delayed relaxation, premature closure

Anomalies of pharyngeal contraction

Multiple anomalies

« Spasms» or increased tonus of the upper sphincter, with or without the sensation of a lump in the throat, have been particularly described in the pathology of reflux [ 1, 2]. The sensation of a pharyngeal globus is significantly associated with an increase in the basal UES pressure sometimes found in anxious subjects.
The discovery of such hypertonus above esophageal anomalies evocative of reflux is an indication for the performance of pH measurement, which may lead to a treatment program suited to treatment of the reflux. Again, an independent elevation of UES tonus may be improved by anxiolytics.
Hypertonus of the UES has been described in patients with gastroesophageal reflux [1-3], in which the sphincter has lost its ability to increase its tonus in response to perfusion of acid [3] or fluid [4]. Further, hypotonus of the UES may be found in cases of myotomy of the cricopharyngeus muscle, after laryngectomy, and in cases of neuromuscular disorder (amyotrophic lateral sclerosis, myasthenia, oculopharyngeal dystrophy, myotonic dystrophy).
The anomalies of relaxation may be divided into 3 groups :
a) Achalasia of the UES . Normally, the sphincter pressure lies below atmospheric pressure, at the level of the esophageal pressure. The achalasia of the sphincter is evidenced by incomplete relaxation in a majority of swallows. It has been described as an isolated finding in children [1] and in the adult after a cerebral vascular accident involving the bulbar region, after bulbar lesions in poliomyelitis, in the stiff-man syndrome, in thyrotoxic myopathy, in oculopharyngeal muscular dystrophy and sometimes after pharyngectomy or laryngectomy. In practice, this anomaly is essentially a disorder of the elderly subject. The correlation between delayed passage of a barium swallow and the manometric findings is poor.
b) Delayed relaxation of the UES is observed in patients exhibiting the Riley-Day type of familial dysautonomy, and is therefore not an affection of the elderly subject.
c) Premature closure of the upper sphincter is involved in the genesis of Zenker's diverticulum [1-5].
Absence or decrease of pharyngeal contraction produces dysphagia even if the function of the upper sphincter is normal. In fact, this function constitutes the motor allowing the alimentary bolus to cross the sphincter passage. The clinical features of such a disorder are sometimes indistinguishable from those of achalasia.
Mixed affections are possible, and an anomaly of pharyngeal contraction may be observed together with an achalasia in a cerebral vascular accident involving the bulb and brain-stem. Again, in oculopharyngeal muscular dystrophy, hypotonus of the UES may be observed together with achalasia. Many other combinations are possible, especially at this time of life when multiple lesions of the central nervous system may occur.
In the body of the esophagus, and apart from disorders associated with a particular pathology, they may be associated with impairment of the quality of peristalsis. Physiologically, the esophageal waves are of less amplitude in the elderly (the range of manometric parameters is much greater at this time of life) and tertiary peristalsis is commoner. Of course, these anomalies may be further augmented by years of exposure to reflux, giving rise to an increased proportion of non-propagated waves which is sometimes a source of dysphagia.
Physiologic achalasia does not exist at the lower sphincter. Megaesophagus occurs most frequently in the fourth decade of life, but remains rare and is evidenced by obvious disturbance of swallowing which usually permits a rapid diagnosis.

## Conclusion

Disturbances of swallowing in the elderly are usually more often associated with motor disorders of the oro-pharyngo-esophageal junction than with disorders of the body or lower sphincter of the esophagus. However, despite an often unequivocal clinical picture of disturbance of swallowing, these disorders may be associated with multiple anomalies and are not well correlated with an achalasia of the UES. Their origins are multiple, but disorders associated with lesions of the central nervous system are by far the commonest.

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## What is the diagnostic value of the different pharmacologic tests ?

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*Volume Primary Motility Disorders of the Esophagus Chapitre Painful esophageal peristalsis (nutcracker esophagus)*

The nutcracker esophagus cannot be detected by routine standard manometry. Therefore, provocation tests should be used in an attempt to reproduce the recurrent symptoms reported by the patient. There are a number of such tests:
- Bernstein's test, or the test of acid perfusion, consists of perfusing 0.IN HC1 into the esophagus. Such perfusion may be made apart from manometry, though we prefer to do so during manometry via a catheter situated in the upper part of the esophagus.
The edrophonium test aims at reinforcing esophageal contractility by intravenous injection of an inhibitor of acetylcholine esterase. This has replaced the ergonovine test, which was not devoid of risk. But it should be noted in passing that the edrophonium test, too, is not altogether devoid of risk in the presence of cardiac arrhythmia, and that it calls for both cardiac monitoring and an intravenous approach. Testing with bethanechol, an analog of acetylcholine, is similar to the above.
- Esophageal distension by means of a balloon or of air consists of inflating a balloon in the esophagus or rapidly transmitting a bolus of air to the upper part of its middle third. This is a useful test, since it is quickly performed and devoid of risks.
Alkalinization is capable of modifying the motor profile of the esophagus [1]. In our hands, this test consists of giving a loading dose of alkali intravenously, followed by a period of hyperventilation, with monitoring of the blood-gases by the capillary route. This is a long test and rather a nuisance for the patient, calling for cardiovascular monitoring, an intravenous approach and a system for sampling blood-gases. However, we have never noted any particular problems with this test in our series, despite these constraints.
These tests may be performed independently during a manometric examination, or, as in our usual practice, in combination, as when an alkalinization test is followed by a Bernstein test, followed in turn by an edrophonium test and then an air test, which produces increased sensitivity to the manometric testing. The sensitivity of such tests as reported in the literature is variable, and we shall not repeat here the numerous published results — which are quoted elsewhere in these pages — but confine ourselves to the main trends emerging from the published material:
1) The aim of the Bernstein test is to reproduce the conditions of reflux disorder, which is not often associated with painful peristalsis since the sphincter is often of normal to high normal tonus. Its sensitivity in this type of pathology is poor, and so is its sensitivity in the investigation of pseudoanginal pathology in general.
2) The alkalinization test seems to markedly increase the amplitude of the peristaltic waves, but it is difficult to perform and in our experience, which includes not just the nutcracker esophagus but also pseudoanginal pain, its sensitivity is 15 p. cent.
3) The balloon test, which seems to be a good provocation test in pseudoanginal disorder, seems less effective in the study of painful peristalsis. In fact, it seems that this test is more suitable for investigating anomalies of mechanoreceptor response.

4) The tests that seem to give the best results in this specific pathology are those that clearly reinforce contractility. There are two possible approaches: activation of acetylcholine synthesis or inhibition of its destruction.
The first of these two approaches is represented by bethanechol. However, its mode of action is not very rapid and may extend over a rather long period, which may be a source of delayed responses sometimes painful for the patient.
The second approach is the inhibition of acetylcholine esterase achieved with edrophonium (Tensilon ®), which is administered intravenously in a dose of 0.008 ml/ kg. This test is made with two injections, one of which is a placebo. As a precaution, the patient should be monitored throughout the test and a syringe containing atropine should be at hand. This substance has a short half-life, which is very suitable for a provocation test. Its administration is followed by performance of a certain number of swallows. This constitutes the most sensitive test for demonstrating the specific disorder of painful peristalsis, since it increases both the amplitude and duration of the peristaltic waves and is without marked effect in the healthy subject.
Since the absence of any disorder of motility at the time of the base examination does not imply that such disorder does not exist, the function of these pharmacologic tests in this context is to attempt to reproduce a pathologic situation which may not be constant in time. The tests acting on the metabolism of acetylcholine (synthesis or breakdown) seem the most effective in reproducing painful peristalsis.

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## What criteria are available to distinguish the syndrome of painful esophageal peristalsis from that of diffuse spasm ?

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*Volume Primary Motility Disorders of the Esophagus Chapitre Painful esophageal peristalsis (nutcracker esophagus)*

It is not always easy on the evidence to distinguish between the different hyper-contractile motor disorders, the more so since the descriptions in the literature vary very considerably from one author to another.
Painful peristalsis (Supersqueeze or nutcracker esophagus).
The nutcracker esophagus is by definition [1] a manometric anomaly characterized by an amplitude of the distal peristaltic waves exceeding the mean value plus two standard deviations in patients presenting with anginal pain and/or dysphagia. The duration of the peristaltic waves may also be increased [1,3, 4]. It should be noted that the propagation of the peristaltic waves is preserved in this disorder, even during the edrophonium test. Thus, there is an abnormal increase in the parameters of esophageal contraction which seems relatively common (by definition, over 2.5 p. cent of the population are in theory affected by such waves) [1].
Table 1. Diagnostic manometric criteria in nutcracker esophagus

| |
|---|
| Peristaltic waves of high amplitude (x ≥ M + 2 SD) |
| Peristaltic waves of long duration |
| Normal progression of peristaltic waves |

Diffuse spasm
Diffuse spasm of the esophagus is defined [2, 4] by the manometric association of simultaneous esophageal contractions in more than 10 p. cent of liquid swallows (8 ml) or 30 p. cent of dry swallows with normal peristaltic waves. This may frequently be associated with repetitive waves (> 3 pressure peaks), high amplitude waves which are sometimes of long duration, frequent spontaneous contractions (apart from swallowing), even anomalies of the lower sphincter (incomplete relaxation partial achalasia) and an elevated rest pressure.
According to Richter [2], the mean amplitude of the waves in the lower esophagus in this disorder is 84 mmHg

(41-216 mmHg) and the normal mean duration 3.8 sec (3-12 sec). Gelfand [4] states that the waves must be spontaneous, with increased duration (> 6 sec)
and amplitude (> 150mmHg). As shown in table 2 below, the amplitude is thus a variable criterion in the diagnosis of diffuse spasm of the esophagus: the absence of spasmodic waves cannot be used to exclude the diagnosis, not can an increased amplitude.
On the other hand, all the authors listed in this table report the presence of simultaneous contractions, so that the presence of these waves does seem to be a necessary criterion in the diagnosis of the disorder.
Table 1. Different descriptions of the disorder of diffuse spasm in the literature (after Richter) [2].

| Year | Author | Intermittent peristalsis | Simultaneous contractions | Repetitive waves | Spontaneous motility | Increased amplitude | Increased duration | A L |
|---|---|---|---|---|---|---|---|---|
| 1958 | Creamer | - | + | + | - | + | + | - |
| 1964 | Roth | + | + | + | - | - | + | - |
| 1966 | Craddock | - | + | + | - | + | - | - |
| 1967 | Gillies | - | + | + | + | - | + | - |
| 1970 | Bennett | - | + | + | + | + | - | - |
| 1973 | Orlando | - | + | + | + | + | - | + |
| 1974 | DiMarino | + | + | + | - | + | - | + |
| 1977 | Mellow | + | + | + | - | + | + | - |
| 1977 | Swamy | - | + | + | + | + | - | - |
| 1979 | Vantrappen | + | + | + | - | + | + | + |
| 1981 | Kaye | + | + | + | - | + | + | + |
| 1982 | Davies | + | + | + | + | + | + | + |
| 1982 | Patterson | + | + | - | - | + | - | - |

Comparative features
The amplitude of the peristaltic waves is by definition increased in the nutcracker esophagus, but this has also been observed by most authors (table 2) in the pathology of diffuse spasm. The duration of the waves may be increased in either disorder. Therefore, these two features are not reliable in the differential diagnosis. On the other hand, most authors are agreed on the propagation of peristaltic waves in the nutcracker type of esophageal disorder and, conversely, on the presence of non-propagated waves during liquid swallows in diffuse spasm [2]. Richter [2] finds this an essential feature in the diagnosis. The proportion of such waves is at least 10 p. cent during liquid swallows (8 ml) and should exceed 30 p. cent when dry swallows are studied, alternating with normally propagated waves. But the proportion of non-propagated waves varies markedly in different studies and may amount to almost 50 p. cent. Moreover, disorders of the type of diffuse esophageal spasm may be accompanied by disturbed motility of the lower sphincter and spontaneous esophageal contractions.

Therefore, in distinguishing between the two disorders, it is essential to conduct a prolonged study of the motility of the body of the esophagus and of the lower sphincter, and to carry out an adequate number of liquid swallows (20 swallows at 30 second intervals in our program) using an adequate volume (minimum 8 ml), since our experience seems to show that the induced propagation depends to a slight extent on the volume of these swallows. Indeed, with volumes of 5 ml, propagation of the peristaltic waves is inconstant in any given patient, whereas with swallows of 8 to 10 ml such propagation of peristalsis seems to be much more constant, allowing of differential diagnosis. Our experience shows that a volume of 8 ml allows easy swallowing for the patient with a good sensitivity in detecting motor disorders (a sensitivity of 87 p. cent in our series).
For perfect interpretation, this type of test requires a minimum of equipment: 3 to 4 pathways for manometric measurement are essential, as is the study of swallowing by electromyography and/or detection by means of a piezoelectric quartz, so as not to require swallowing in a patient who has just had a dry swallow or division of the swallow into two stages (two swallows of small volumes).
Provided these precautions are observed, it is easy to interpret this parameter, which is essential to the distinction of these two entities.

Conclusions
The distinction between the nutcracker esophagus (painful peristalsis) and diffuse spasm is based essentially on the presence in the latter disorder of frequent non-propagated waves occurring simultaneously at different levels of the body of the esophagus during liquid swallows.

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## What is the incidence of intermittent occurrence of simultaneous contractions ?

**G. Cargill (Paris)**
*Volume Primary Motility Disorders of the Esophagus Chapitre Diffuse esophageal spasm (Corkscrew esophagus)*

The classical symptoms of diffuse spasm are retrosternal thoracic pain, sometimes of anginal nature, and/or dysphagia, as well as tertiary contractions at radiologic examination and, finally, characteristic specific manometric anomalies such as simultaneous esophageal contractions in more than 10 p. cent of wet swallows, normal intermittent peristalsis, repetitive or at least triphasic contractions, prolonged duration of contractions, increased amplitude of contractions, spontaneous contractions, sometimes incomplete relaxation of the lower sphincter and elevated basal pressure [1,2].
The type of anomaly found changes with the equipment used, the peristaltic waves being much greater in amplitude with a low compliance system, or with micro-transducers in situ, whence the differences in description in the literature (table 1).
The only sign found by every author is an anomaly of propagation of the peristaltic waves, but this proportion varies from one patient to another. It is at least 10 p. cent after liquid swallows (this is a diagnostic criterion, since a lesser proportion may be physiologic). If studies are made with dry swallows, the proportion must be at least 30 p. cent [3,4] to confirm the diagnosis.
However, a study using dry swallows may give rise to errors in diagnosis since there exist healthy volunteers exhibiting 80 to 100 p. cent of non-propagated waves after dry swallows [1],
Richter reports a mean incidence of around 40 p. cent, varying according to the patients from 20 to 90 p. cent, in a series of 95 patients exhibiting such disorders.

Table 1. Different descriptions of the disorder of diffuse spasm in the literature.

| Criteria of diffuse spasm of the esophagus (after Richter)[l] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Author | Intermittent peristalsis | Simultaneous contractions | Repetitive waves | Spontaneous motility | Increased Increased amplitude duration | | Ar LE |
| 1958 | Creamer | - | + | + | - | + | + | - |
| 1964 | Roth | + | + | + | - | - | + | - |
| 1966 | Craddock | - | + | + | - | + | - | - |
| 1967 | Gillies | - | + | + | + | - | + | - |
| 1970 | Bennett | - | + | + | + | + | - | - |
| 1973 | Orlando | - | + | + | + | + | - | + |
| 1974 | DiMarino | + | + | + | - | + | - | + |
| 1977 | Mellow | + | + | + | - | + | + | - |
| 1977 | Swamy | - | + | + | + | + | - | - |
| 1979 | Vantrappen | + | + | + | - | + | + | + |
| 1981 | Kaye | + | + | + | - | + | + | + |
| 1982 | Davies | + | + | + | + | + | + | + |
| 1982 | Patterson | + | + | - | - | + | - | - |

In our own experience, based on 18 patients showing this disorder and observed during the last year, the proportion of non-propagated waves is not very different, being equal to 36 p. cent with extremes of 12 and 57 p. cent.
Finally, although the presence of non-propagated waves is essential to the diagnosis, it is not enough in itself since such anomalies may be seen in reflux pathology [5, 6], neuropathies, the collagen disorders and pseudo-obstructions.

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# Do recording systems permit correct measurement of the true amplitude of the esophageal waves ?

**G. Cargill (Paris)**

*Volume Primary Motility Disorders of the Esophagus Chapitre Diffuse esophageal spasm (Corkscrew esophagus)*

The classical systems for measuring intra-esophageal pressures use measurement catheters employing two different technologies : water infusion, where the pressure transducers are placed on the outside of the patient, and micro-transducers in situ, where the small electronic receptors are situated in the sound. The collection of pressure variations differs from one system to another, and so does the analysis of the results. Various other parameters play a part in measurement and are essentially linked to the polygraphic systems for collecting the signal. It should be noted, however, that exact measurement of the pressures is impossible.
Any system of measurement, however sophisticated, can only provide an image of what is happening around the receptor, this image being determined by the capacities of the different components of the chain of data gathering and measurement ; and, as in all electronic chains, the exit signal is a direct function of the least effective component of the entire chain.
Perfused systems
These consist of a sound [1] composed of several small capillary tubes which are perfused with distilled, gas-free water at a constant flow-rate (0.5-0.7 ml/min) by means of a pneumohydraulic system of low compliance. They are reliable and easy to use and the external position of the pump makes for easy maintenance.
(In our experience over the last 5 years, 1 capillary tube was changed each year for an annual average of 2448 examinations, using a 4-path Arndorfer pump). The same applies to the receptors, which are rarely subject to breakdown [1] (in our experience no troubles in 5 years for 5 Statham P231D receptors).
This type of perfusion system has progressively replaced perfusers of plunge-syringe type because of the very variable flow in the latter, under the influence of
variations in intraesophageal pressure [2]. In fact, these systems, designed for injection of fluids at low (venous) pressures, have a flow which is a function of the counterpressure exerted at the perfusion site (figure 1) i.e. at the ends of the capillary tubes. This flow becomes zero for the values attained during physiologic

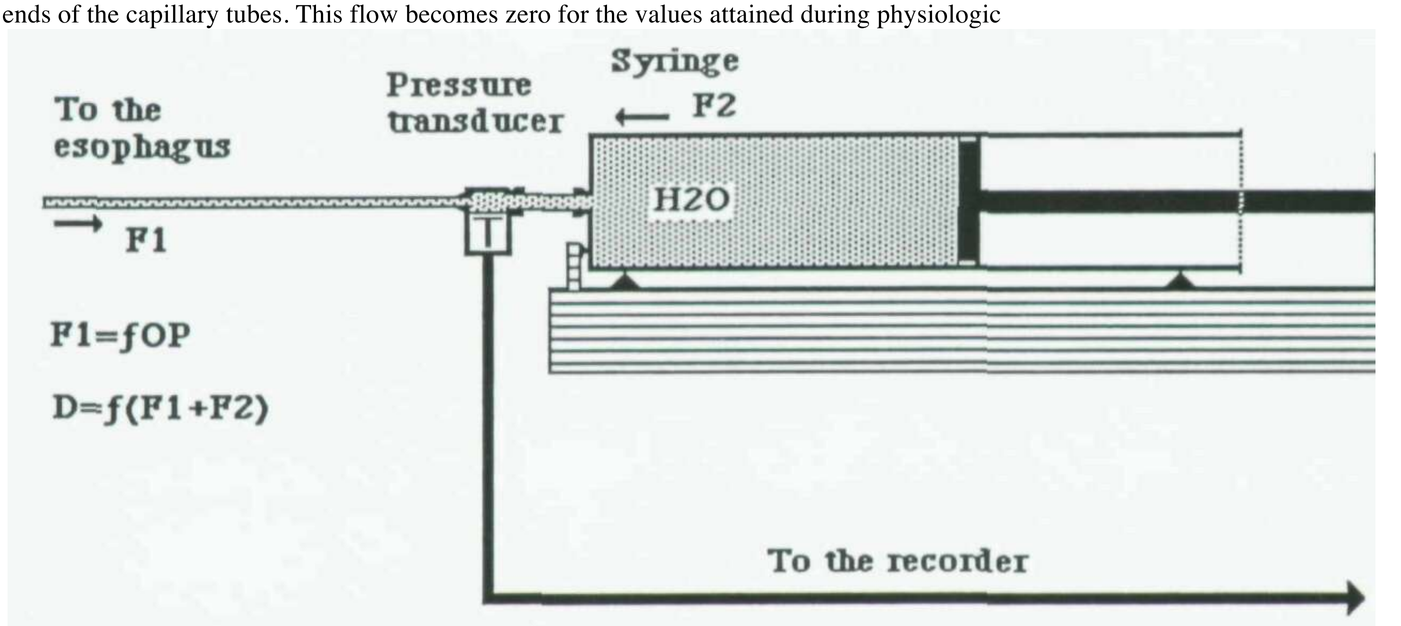


Figure 1. Syringe perfusion system.

Fl = force generated by counterpressure associated with esophageal
motility.
F2 = perfusion pressure generated by plunger syringe.
D = outflow (function of differential pressure).
phenomena in the esophagus, such as contraction of the body of the organ on swallowing or during study of the upper sphincter. In the study of pathologic situations, where the esophagus and/or the lower sphincter exhibit extreme anomalies of tonus, this arrest of perfusion is prejudicial to correct understanding of the disorders. Moreover, because the syringes of these systems are not independent (figure 2), an elevation of pressure in one pathway decreases the perfusion flow

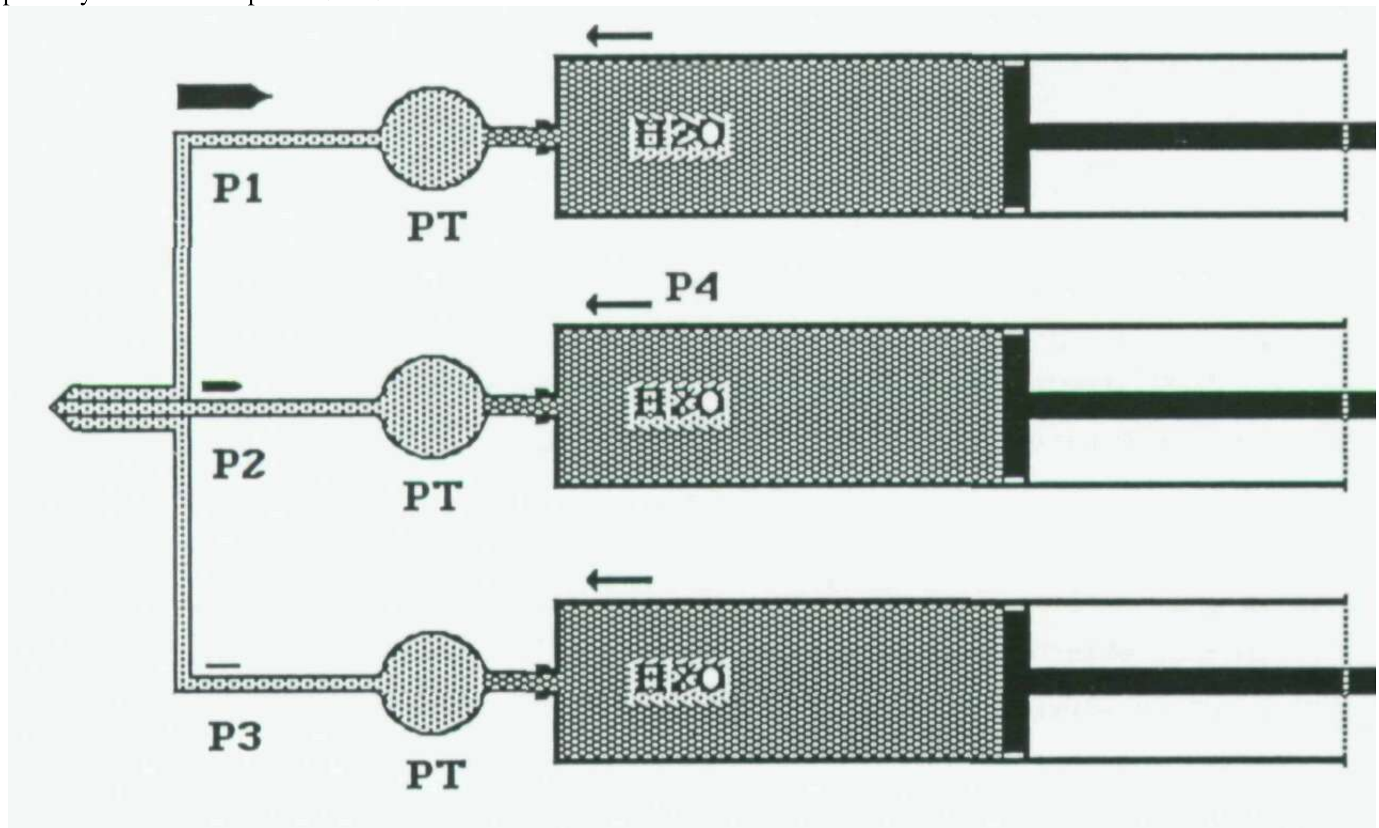


Figure 2. Syringe perfusion system. If the counterpressure exerted by the esophagus on one of the pathways is considerable, the system is no longer perfused.
in the entire system. This has the corollary of disturbing pressure measurement by virtue of the compliance phenomenon.
The principle of the pneumohydraulic pump [2] is based on an autonomous flow for each measurement pathway and on the least variation of flow in relation to the esophageal motor phenomena (figure 3). The perfused water, doubly distilled and degasified, is stored in a pressurized reservoir at a pressure of the order of 15 PSI, adjustable by means of a relief valve. A pipe emerging from this reservoir

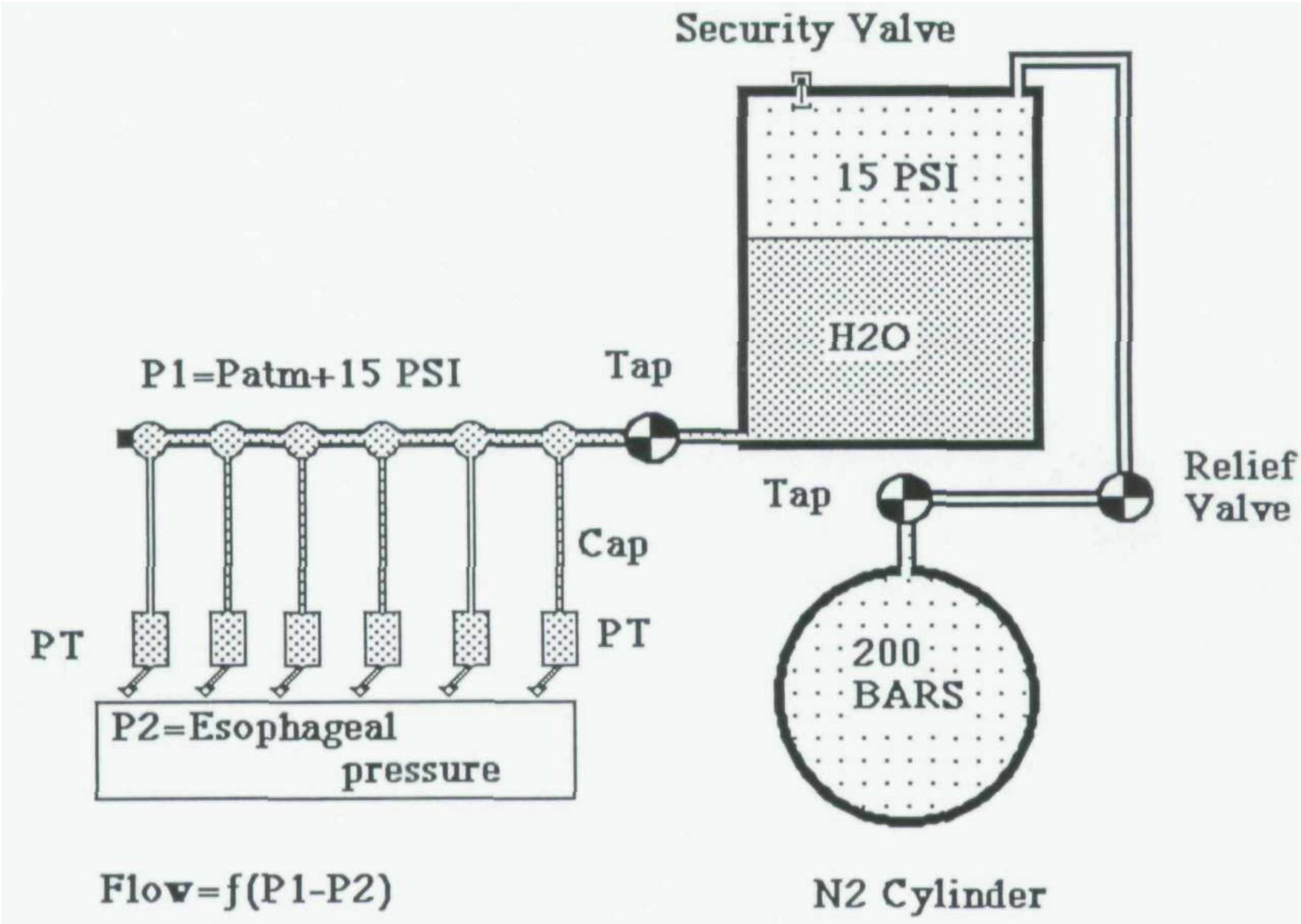

Figure 3. Low compliance perfusion system for esophageal manometric studies.

supplies a series of capillary tubes which convey water to the different catheters of the sound. Under these conditions, the flow in each pathway is a function of the diameter and length of the capillary tubes and the difference in pressure between the pipe, i.e. the atmospheric pressure plus 15 PSI (or one atmosphere) and the distal end of the capillary tube connected to the pressure transducer. In normal conditions, the counterpressure generated by esophageal motility varies from -10 cm $H_20$ (≈ -1 KPa) to around 100 cm $H_20$ (≈ 10KPa), with a variation of flow of around 10 p. cent for the highest physiologic pressures observed in the esophagus. This is not the case in motor disorders of the type of diffuse spasm of the esophagus, where the pressures developed may reach much higher values. In this type of pathology, we have observed peristaltic waves with an amplitude of more than 400 cm $H_20$ (≈ 40KPa). In these particular conditions, measurement of the pressure peaks may be impaired, especially if there are very rapid pressure variations.

Analysis of the function dp/dt as an index of muscle contractility is increasingly impaired as the pressures increase, since the flow of fluid lessens. It should be noted

that the use of such systems implies monitoring of the fluid circuit in order to expel any bubbles of air it may contain, which considerably increase compliance. This involves the use of doubly distilled and degasified water, and of a poorly soluble propellant gas : nitrogen or, even better, argon.

It should be noted, too, that, in physical terms, these two techniques do not measure a pressure but a counterpressure (figure 4), since what is being recorded in this way are the effects of contraction of the esophageal wall on flow in the catheters ; the esophageal contraction occludes the orifice of the catheter, thus increasing the pressure within it and in the measurement chamber of the transducer.

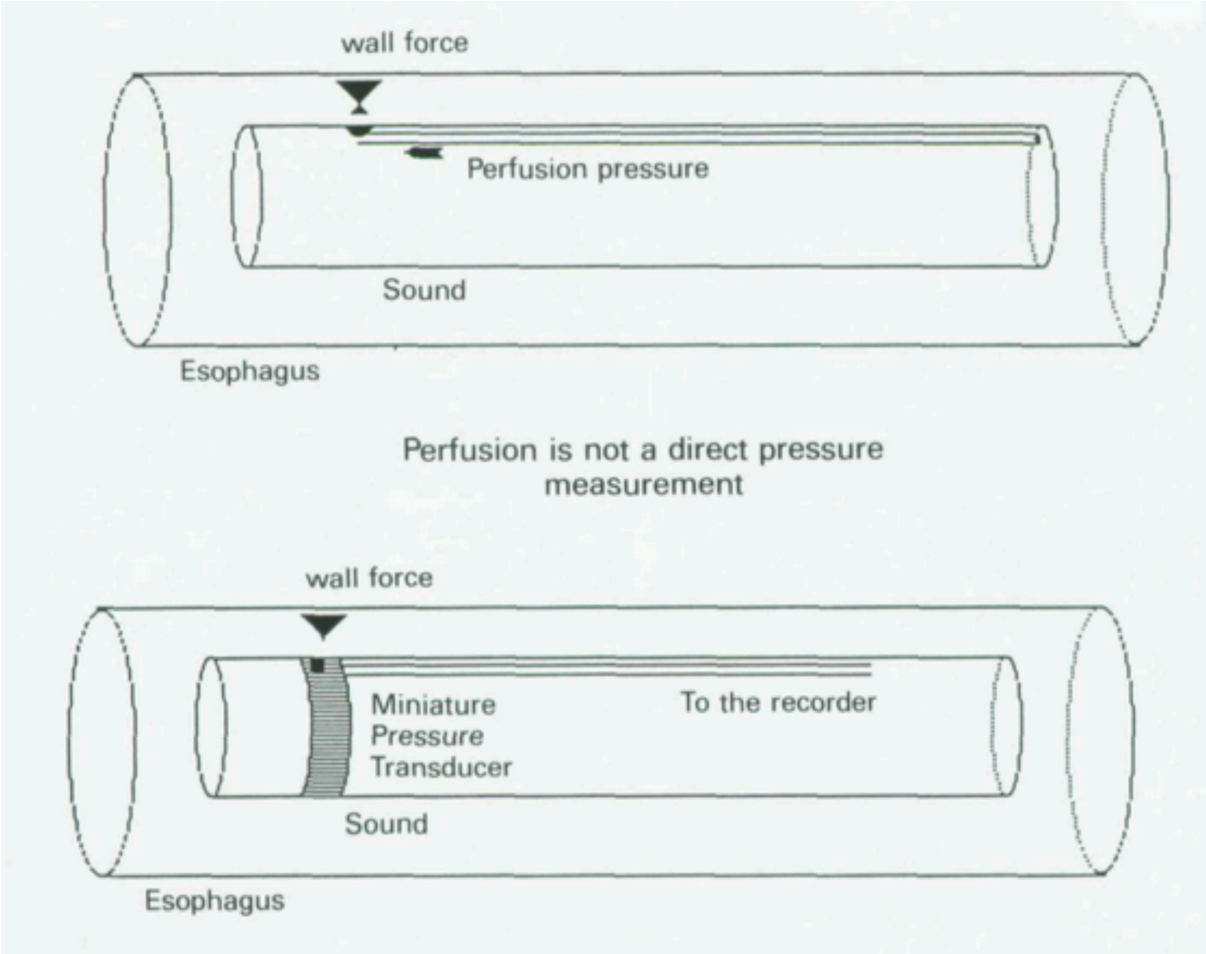

Figure 4. Miniature pressure transducer for direct measurement.

In situ microtransducers

Unlike previous techniques, this technology measures the pressure in the esophageal cavity directly (figure 4). Measurement here is relatively directional. The wave-band passing from such microtransducers is a high one (>10KHz), which permits virtually instantaneous measurement of the pressure variations. Since variations of over 2500 mmHg/sec can be dealt with, this means that the problems of compliance encountered with perfused systems can be completely ignored with such possibilities. However, if the measurement is to approximate to reality, the scale of measurement must correspond to the values obtained in the esophagus.

While a scale of -5 KPa/+20 KPa is adequate for study of the motility of a normal esophagus, this is not the case for the study of esophageal spasm where the scale of measurement may be limited. Therefore it is necessary to make a careful choice of the range of measurement and the scale of reproduction of the signal.

Besides this limiting function of choice of microtransducer, it is to be noted that variations in measurement are sometimes observed connected with shunt from the transducer, and may be associated with variations in temperature. This last criticism is becoming increasingly inapplicable to modern generations of transducers.

The use of such technologies allows a much more proximate measurement of the true pressures obtained in the alimentary tract.

Other factors influencing measurement

Parameters other than measurement techniques influence the measurement of pressure. They include the following factors: the presence of air in the esophagus prevents direct application of the force from the esophageal wall to the transducer, which creates a certain degree of intraesophageal compliance not associated with the measurement technique but certainly at the site of measurement and its content. In certain situations where there is salivary stasis in the esophagus, this presence of air may give rise to marked derangements of measurement.

The use of frequency filters may also smooth out the pressure variations and thus serve to limit the pressure maxima, especially if the peak of maximum pressure is reached over a short period.

It should be remembered in this context that the manometric signal has a frequency of 8 to 10 Hz. Thus, to have due regard for the signal, the frequency filter of the recorder must be adjusted for at least 30 Hz (i.e. a value exceeding at least 2.5 times the value to be reproduced : Maxwell's Law).

Finally, the scale of reproduction of the signal on the polygraph must be adjusted to the signal. If the signal exceeds the scale, it will « ceiling out», which prevents correct measurement. In this sense, the development of a polygraph with super-imposable tracks is a step forward, the ideal being the ability to modify the amplification of the signal during measurement if this exceeds the scale of reproduction, and so to adjust the scale of reproduction to the effectively measured signal. Unfortunately, this modification of the scale sometimes leads to modification of the reference zero if the different parameters of the polygraph are not perfectly adjusted and calibrated. Again, the increasingly practised computerized assessment of values does not always allow exact assessment because of digitalisation that is sometimes too low (less than 2.5 times the frequency to be reproduced) and a sometimes ill-adjusted scale.
All these limitations mean that measurement of the true amplitudes of the waves in the pathology of diffuse spasm depends on a flawless technology adjusted to the type of measurement to be carried out.
Conclusions
Thus, the measurement of the true amplitude of the esophageal waves in the disorder of diffuse spasm depends on the technology employed. Measurement does not seem reliable with a perfused system of plunger syringe type. It is greatly facilitated by the use of pneumohydraulic systems of low compliance (except perhaps for waves of very high amplitude), or by means of sounds with in situ microtransducers which measure the pressure virtually instantaneously because of their extremely low intrinsic compliance.
Apart from these technologic precautions, the reproduction factors (frequency filters, signal amplification) must be adjusted to the signal measured. But the real question to be faced in this problem is surely the following : « What is the usefulness of this precise measurement of amplitude, once the measurement is close enough to reality and the diagnosis of diffuse spasm can be made ? » The answer to the question thus raised is more permissive, now that systems perfused by means of low compliance pneumohydraulic infusers permit relatively correct assessment of the motility of the body of the esophagus and of the lower sphincter, factors essential to the diagnosis of diffuse spasm.

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# Can diffuse esophageal spasm be asymptomatic ?

**G. Cargill( Paris)**
*Volume Primary Motility Disorders of the Esophagus Chapitre Diffuse esophageal spasm (Corkscrew esophagus)*

The classical symptoms of diffuse spasm are retrosternal thoracic pain, sometimes of anginal nature, and/or dysphagia, as well as tertiary contractions at radiologic examination and, finally, characteristic specific manometric anomalies such as simultaneous esophageal contractions in more than 10 p. cent of wet swallows, normal but intermittent peristalsis, repetitive and at least triphasic contractions, prolonged duration of contractions increased amplitude of contractions, spontaneous contractions, sometimes incomplete relaxation of the lower sphincter and elevated basal pressure [1].
The type of anomaly found changes with the equipment used, the peristaltic waves being much greater in amplitude with a system of low compliance or with micro transducers in situ. Hence the differences in description in the literature (table I).
The dominant symptoms are retrosternal pain which may radiate to the back and shoulders, sometimes mimicking angina and sometimes relieved by nitro-compounds, and dysphagia. These symptoms are sometimes occasional, intermittent and moderate, sometimes severe in others. The pain is not necessarily related to swallowing but may be influenced by food intake, notably by hot or iced fluids. The pain may waken the patient and is often increased by stress.
However, the signs described above are alarm signs requiring investigations, including manometry, leading to the diagnosis. There is no reason to think that

Table 1. Different descriptions of the disorder of diffuse spasm in the literature.

Criteria of diffuse spasm of the esophagus (after Richter)[l]

| Year | Author | Intermittent peristalsis | Simultaneous contractions | Repetitive waves | Spontaneous motility | Increased amplitude | Increased duration | Ar LI |
|---|---|---|---|---|---|---|---|---|
| 1958 | Creamer | - | + | + | - | + | + | - |
| 1964 | Roth | + | + | + | - | - | + | - |
| 1966 | Craddock | - | + | + | - | + | - | - |
| 1967 | Gillies | - | + | + | + | - | + | - |
| 1970 | Bennett | - | + | + | + | + | - | - |
| 1973 | Orlando | - | + | + | + | + | - | + |
| 1974 | Di Marino | + | + | + | - | + | - | + |
| 1977 | Mellow | + | + | + | - | + | + | - |
| 1977 | Swamy | - | + | + | + | + | - | - |
| 1979 | Vantrappen | + | + | + | - | + | + | + |
| 1981 | Kaye | + | + | + | - | + | + | + |
| 1982 | Davies | + | + | + | + | + | + | + |
| 1982 | Patterson | + | + | - | - | + | - | - |

there may not be certain silent, asymptomatic forms. Gelfand [2] cites the existence of such forms without reporting their incidence.

To identify the possible incidence of such anomalies, it would be necessary to carry out manometric investigations in a reference population to establish the prevalence of the disease. We ourselves have never found anomalies suggestive of diffuse esophageal spasm in healthy volunteers studied at the termination of pharmacoclinical or pharmacologic studies.

Apart from diffuse spasm discovered during assessment for suggestive symptoms, we have found anomalies suggestive of DES in a patient aged 11 years referred for systematic review, with the picture of an adrenal insufficiency syndrome: alacrimia, associated classically in childhood with sphincteric achalasia. This child did not present any disorder of swallowing clinically ; there was no dysphagia, either for solids or liquids, and no retrosternal pain.

Manometric examination was called for as a routine in the context of assessment of the Addison's disease. The manometric study demonstrated an inferior sphincter of normal tonus at normal level (varying with the tracks from 2 to 3.5 KPa), with relaxation on swallowing not always perfect (varying by 75 to 100 %), and peristaltic waves of increased duration sometimes reaching an amplitude of 40 to 65 KPa.

These waves were non-propagated as much after dry swallows as after moist swallows. They alternated with rare propagated waves and waves showing normal amplitude and propagation (17 % of waves observed on the tracing). When their amplitude was increased, their duration was likewise increased, amply exceeding 6 seconds, sometimes exceeding 10 seconds. All these anomalies combine in a pathology of diffuse spasm capable of developing, in our view, towards an achalasia typical of Addison's disease. Are we entitled to speak of diffuse spasm in cases like this ?
This is uncertain, since the generally accepted definitions of the disorder include pain.
To sum up, diffuse spasm of the esophagus seems to be observable during non-suggestive symptoms, a case discovered during routine investigation being reported here. No arguments can be advanced against the existence of such asymptomatic disorders, such as are reported elsewhere by some authors. However, since the definition of diffuse spasm includes pain, it might perhaps be more logical in such cases to speak of a manometric syndrome of diffuse spasm, so as to indicate the difference from classical diffuse spasm.

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# What is to be expected from the new technics of electromanometry ?

**G. Cargill (Paris)**
*Volume Primary Motility Disorders of the Esophagus Chapitre Achalasia of the S.E.S. Oropharyngeal dysphagia*

The development of techniques for the study of alimentary motility provides an increasingly improved understanding of the motor phenomena, especially those at the oro-pharyngo-esophageal junction.
After the development of low-flow, low-compliance perfusion systems, that of in situ pressure micro-transducers now allows more valid measurement of the pressures and their variations.
The very short response time of these transducers, their very high wave band and their small diameter make it possible to follow the sequence of motor phenomena instantaneously, so allowing a better study of pharyngo-esophageal synchronism.
This permits a more refined study, which may possibly be coupled with electromyographic and/or laryngo-videoendoscopic studies [1] or with radiologic studies [1,2].
Study of the upper esophageal sphincter is tricky [1, 2, 3,4], as evidenced by the wide range of values published in the literature. The existence of an asymmetry and its sensitivity to perfusion mean that the values measured are subject to caution (table 1).
The existence of rapid variations in tonus [3] (figures 1, 2) implies an elevated frequency acquisition and/or a filter placed in a position exceeding 48 Hz, and the function §p/5t must allow for variations of several thousands of mmHg a second (>2 500), which is not possible with a perfused system or a Dent's sound. The use of in situ pressure micro-transducers allows such a study and provides a better understanding of the fine variations in motility. Thus, the reactive hypertonus that follows swallowing is more marked after the absorption of solids or semi-solids than after swallowing water [3], whereas swallowing gives somewhat less relaxation [3]. The capacities of these sensors are only limited by movements of the sound in swallowing, allowing such detail that it is now possible to combine these curves with other technologies.

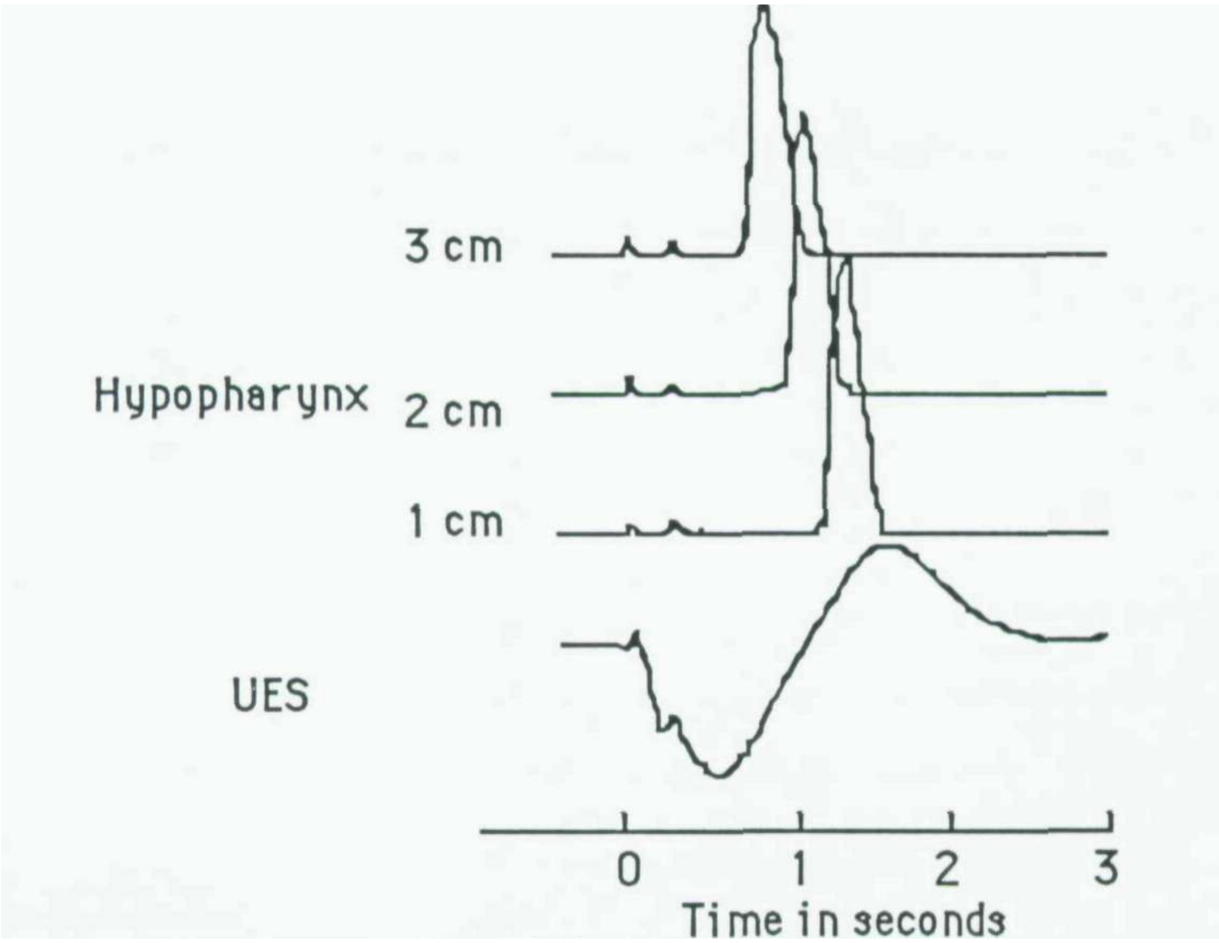

Figure 1. Upper Esophageal Sphincter : relaxation during swallowing.

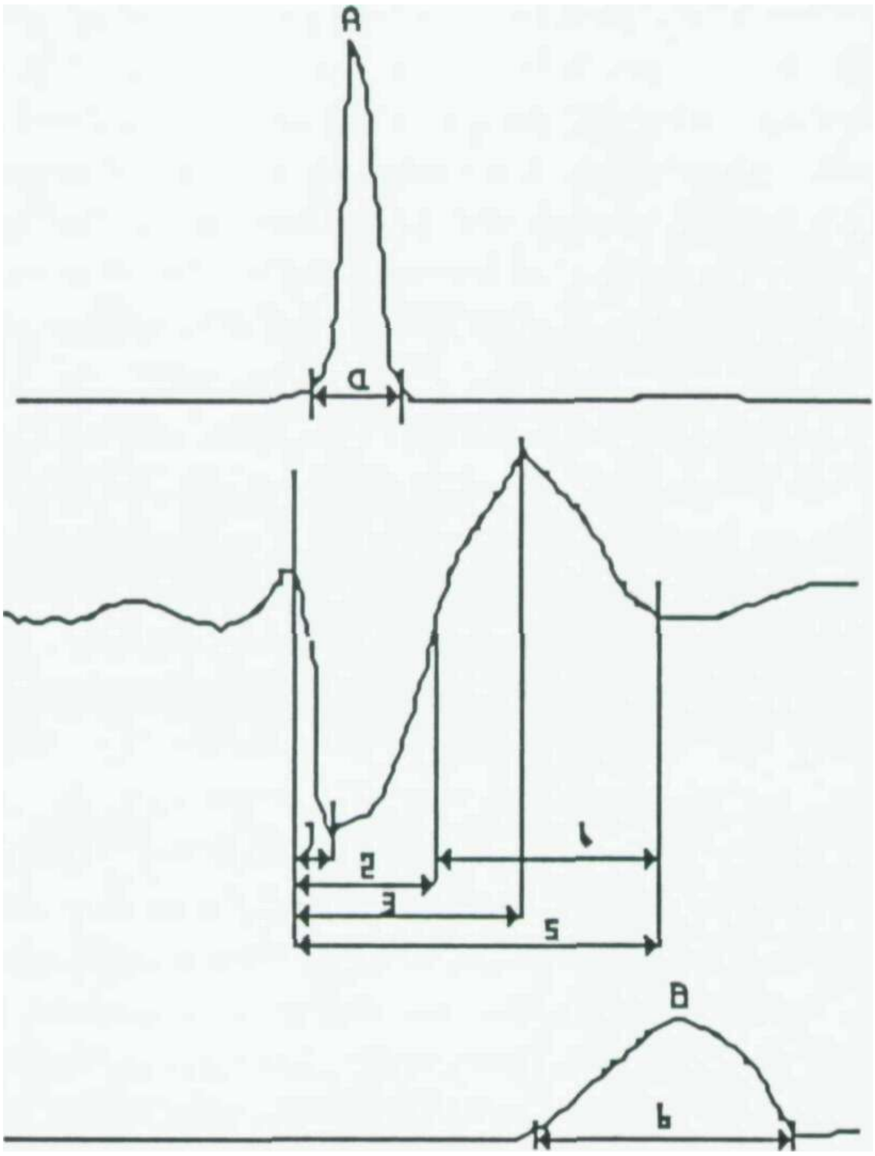


Figure 2. Time intervals calculated in wet swallow analysis: AB = pharyngoesophageal wave, a = duration pharyngeal contraction, b = duration UES contraction, 1 = time to minimum relaxation, 2 = duration relaxation, 3 = time to peak after contraction, 4 = duration after-contraction, 5 = UES swallow complex duration.

Table 1. Pressure of upper sphincter in several studies [3, 6]

| Author | Year | No. of subjects | Max. pressure (mmHg) | Min. pressure | Type o |
|---|---|---|---|---|---|
| Winans | 1972 | 18 | 101 | 32 | P-LC-C |
| Berlin et al | 1977 | 6 | 81 | 46 | P-LC-C |
| Welch et al | 1979 | 13 | 136 | 50 | P-LC-C |
| Gerhardt et al | 1980 | 20 | 101 | 48 | P-LC-C |
| Hellmans et al | 1981 | 10 | 115 | 30 | P-LC-C |
| Knuff et al | 1982 | 15 | 92 | 42 | P-LC-C |
| Grenn | 1986 | 20 | 64 | 29 | P-LC-C |
| Wilson et al | 1989 | 50 | 40 | | SPT-O |
| | | | 53 | | P-LC |
| | | | 83 | | DS |

P = perfused catheter, LC = low-compliance pump, O = oriented catheter, SPT = miniature pressure transducers, DS = Dent sleeve

The combination of these very sensitive technologies, using a barium swallow and video recording, with reproduction of the pressure curves on the image allows even more detailed studies of swallowing [2, 5], since the pressure variations recorded do not always correspond to the known structural variations of the oro-pharyngo-esophageal passage. It is thus possible to show (figure 3) that opening of the sphincter occurs during laryngeal ascent, that opening is coordinated with hyoid movements, and that there exists a correlation between the pressure linked with the alimentary bolus (vector force) and the diameter of the sphincter during its opening (figure 4). The generation of the propulsive vector of the alimentary bolus (pressure of the alimentary bolus) coincides with the posterior thrust of the tongue which culminates in contact with the pharyngeal wall and initiates pharyngeal peristalsis. Increase in the volume swallowed is associated with increase of the vector force and hastens the passage of the anterior part of the bolus. The duration of opening of the sphincter increases as a function of anterosuperior hyoid movement.

Analyses including video recording of pharyngeal motility (laryngo-pharyngeal videoendoscopy) show relatively comparable findings [1].

Electromyography (EMG) permits the precise study of the function of each muscle group during the different phases of swallowing. However, it remains difficult to perform, for the external recordings are, in our experience, far too imprecise to supply information about the whole of one region, while recordings by implanted electrodes are difficult for the patient to tolerate, which not only causes discomfort but may modify the local physiology. Few studies combining EMG and manometry and/or other technologies are currently available. However, they are in theory the ideal methods for a more precise study of the very complex and rapid phenomena of the initial phase of swallowing.

The contribution of these technologies would be of only physiologic interest if disorders of swallowing were not so common in the aged. These are a source of both functional handicap and malnutrition [6]. Oropharyngeal dysphagia may be linked with numerous causes of complex mechanism, collected in table 2 below.

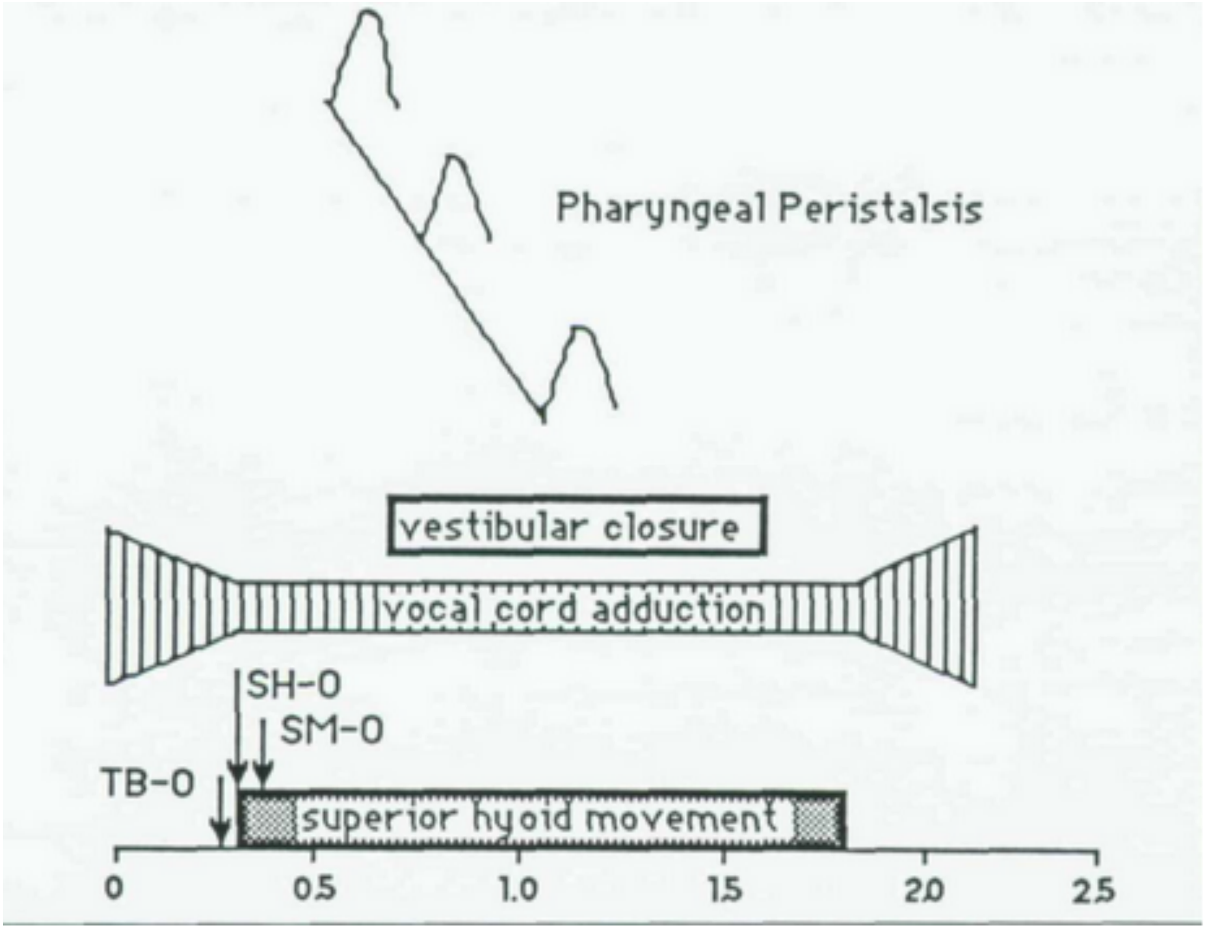

Figure 3. Relationship of deglutitive vocal cord to other events of the oropharyngeal phase of swallowing during dry swallows (in Shaker: et al, Gastroenterology 1990).

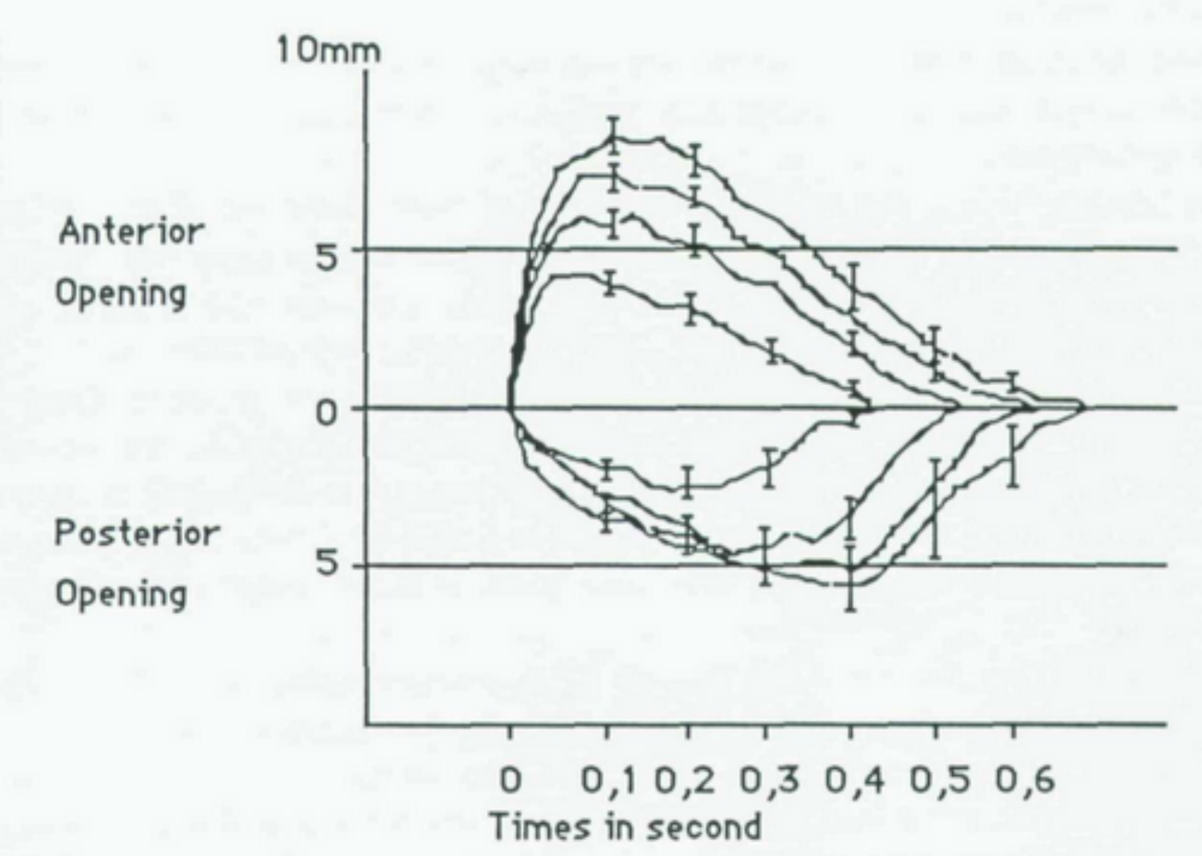

Figure 4. LIES opening as a function of bolus volume (in : Jacob et al Gastroenterology 1989).

Some of these may be found in children and infants, others are more specific to the elderly subject. Manometric study may be a determining factor in the diagnosis of some of these disorders, as in the case of scleroderma, but it is more often a factor of orientation

Table 2. Neuromuscular anomalies causing oropharyngeal dysphagia (after Green, [6])

Central nervous system

Cerebrovascular accident with bulbar involvement or pseudobulbar palsy, Parkinson's disease, multiple sclerosis, amyotrophic sclerosis, syringobulbia, « stiff man syndrome », brain-stem tumor, Duchenne's disease, Riley-Day syndrome or dysautonomia lesions associated with delivery, neonatal bulbar damage, « Immaturity » of the brain-stem.

Peripheral nervous system

Mononeuritis, neuropathy (diabetic, alcoholic, diphtheritic, tetanus, botulism...)

Neurotransmission - motor end plate

Myasthenia

Muscle

Myotonic dystrophy, oculopharyngeal muscular dystrophy, polymyositis and dermatomyositis, metabolic myopathies

and understanding in locating the physiopathologic origin of the disorders, either confined to the pharyngo-sphincteric region or extending to the whole of esophageal motility.
Note that the results presented here are derived from numerous studies which still need confirmation by other complex studies of swallowing using more precise techniques. Most of the existing studies were made with perfused systems, and the results are sometimes contradictory from one author to another.
The disorders found in the oropharynx may logically be grouped under a certain number of motor entities in terms of the anomalies found on manometric examination. These anomalies (table 3) are of several types : those only involving the pathology of the sphincter (whose existence is disputed by some) and those comprising anomalies above the sphincter (and possibly associated with the foregoing).
Clinically, functional disorders of the SES are associated with dysphagia, essentially for liquids, regurgitation and the feeling of a lump in the throat.
« Spasms », or upper sphincters with increased tonus, with or without the feeling of a lump in the throat, have been particularly described in the pathology of reflux [6, 7]. The feeling of pharyngeal globus is significantly associated with the increase of basal SES pressure sometimes found in anxious subjects.
The discovery of such hypertonus above esophageal anomalies suggestive of reflux will lead to performance of pH measurement, which may result in an appropriate plan of treatment for reflux.
Likewise, an isolated elevation of SES pressure can be ameliorated by anxiolytics.
Table 3. Synthetic table of causes of motor disorders

| |
|---|
| Motor causes of oropharyngeal dysphagia : list of motor disorders |
| Hypertonus of superior sphincter |
| Hypotonus of superior sphincter |
| Anomalies of relaxation : |
| Achalasia or incomplete relaxation, delayed relaxation, premature closure |
| Anomalies of pharyngeal contraction |
| Multiple anomalies |

Hypotonus of the SES has been described in patients with gastroesophageal reflux [6, 8, 9], where the sphincter has lost its ability to increase in tone in response to acid [8] or liquid [10] perfusion. This hypotonus is found particularly in children with reflux associated with chronic bronchopneumopathy [9].
Further, hypotonus of the SES may be found in cases of myotomy of the cricopharyngeus muscle, after laryngectomy, and in cases of neuromuscular disorder (amyotrophic lateral sclerosis, myasthenia, oculopharyngeal dystrophy and myotonic dystrophy).
The anomalies of relaxation may be divided into three groups :
a) Achalasia of the SES .
Normally, the sphincter pressure falls below atmospheric pressure to the level of the esophageal pressure. Achalasia of the sphincter is indicated by incomplete relaxation in a majority of swallows. It has been described as an isolated finding in children [6] and in adults after cerebral vascular accidents involving the bulbar region, after bulbar poliomyelitis, in the «stiff man» syndrome, thyrotoxic myopathy, oculopharyngeal muscular dystrophy and sometimes after pharyngectomy or laryngectomy. In practice, this anomaly is essentially an affection of the elderly.
b) Delayed relaxation of the SES is seen in patients exhibiting familial dysautonomia of the Riley-Day type, in which there are anomalies of sucking and swallowing. In this context [6] sphincteric opening is delayed while pharyngeal motor activity is normal.
c) Premature closure of the upper sphincter is implicated in the genesis of Zenker's diverticulum [6, 11], although this anomaly is not found in all the manometric studies on this subject. The finding of such a disorder in a patient with a diverticulum, in the absence of reflux, is an indication for a myotomy combined with diverticular resection in order to prevent long-term recurrence.
The absence or decrease of pharyngeal contraction produces dysphagia, even if function of the superior sphincter is normal.
Indeed, this function represents the motor permitting the alimentary bolus to cross the sphincteric passage.

Mixed affections are possible and anomalies of pharyngeal contraction associated with pharyngo-sphincteric asynchronism may be seen, for instance in hypoxic birth injuries, or an anomaly of pharyngeal contraction plus achalasia in cerebral vascular accidents involving the bulb and brain-stem. Hypotonus of the SES as well as achalasia may also be seen in oculopharyngeal muscular dystrophy. Many other combinations are possible.

Conclusions

Employment of new manometric techniques allowing precise and reliable recording of the movements of the SES allow a more exact diagnosis of the motor anomalies of this region. This has two main consequences: first, a better understanding of the disorders involved in oropharyngeal dysphagia and their easier integration into a set of symptoms, and second, more appropriate plans of treatment in situations where the disorders found may be corrected, either by medical or surgical treatment. Further, the combination of these manometric techniques with video-endoscopic and/or radiologic and/or electromyographic recordings will allow a better understanding of the relations between the different types of signals, while an understanding of the observed concordances will lead to a better knowledge of the physio-pathology of the first stages of swallowing.

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