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VIEW POINT

# High-resolution manometry: A new gold standard to diagnose esophageal dysmotility?

## *Manométrie haute résolution : nouvel examen de référence pour le diagnostic des troubles de la motricité œsophagienne ?*

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## Introduction

Esophageal manometry is considered the gold standard for the assessment of esophageal motility after mechanical obstruction and mucosal disease have been excluded by endoscopy. The conventional technique uses a probe with four to eight variably spaced pressure sensors positioned in the esophageal lumen to monitor pressure changes during swallowing. During the study the probe may need to be repositioned to examine the entire esophagus and to focus on a particular area of interest.

Esophageal high-resolution manometry (HRM) was first described by Clouse et al. in the 1990s [1]. This technique is characterized by an increased number of pressure sensors (21 to 36 one-centimeter spaced sensors) spaced closely together (< 1—2 cm apart). Thus esophageal intraluminal pressure can be more completely defined from the hypopharynx to the proximal stomach with minimal spatial gaps between recordings sites and with minimal movement related artifacts [2]. More recently, the introduction of solid-state high fidelity sensors allows pressure measurements all around the whole esophageal circumference [3].

Data from HRM can be illustrated in the context of esophageal pressure topography (EPT) plots by defining pressure domains with isobaric conditions. The pressure topography plots utilize color to separate the pressure domains and this information can be leveraged to clearly identify the esophagogastric junction (EGJ) and the functional anatomy of the esophagus (Fig. 1). Moreover, the diagnostic yield may be increased especially in cases of dysphagia. Finally technical improvements coupled with pressure topography analysis should simplify esophageal manometric exploration and the interpretation of esophageal motor dysfunction.

## A better assessment of esogastric junction?

HRM defines EGJ morphology and location more accurately than conventional low-resolution manometry [2]. Despite the respiratory and swallowing-induced EGJ mobility, the borders of EGJ are easily recognized with EPT plots and the relative positions of the crural diaphragm and the lower

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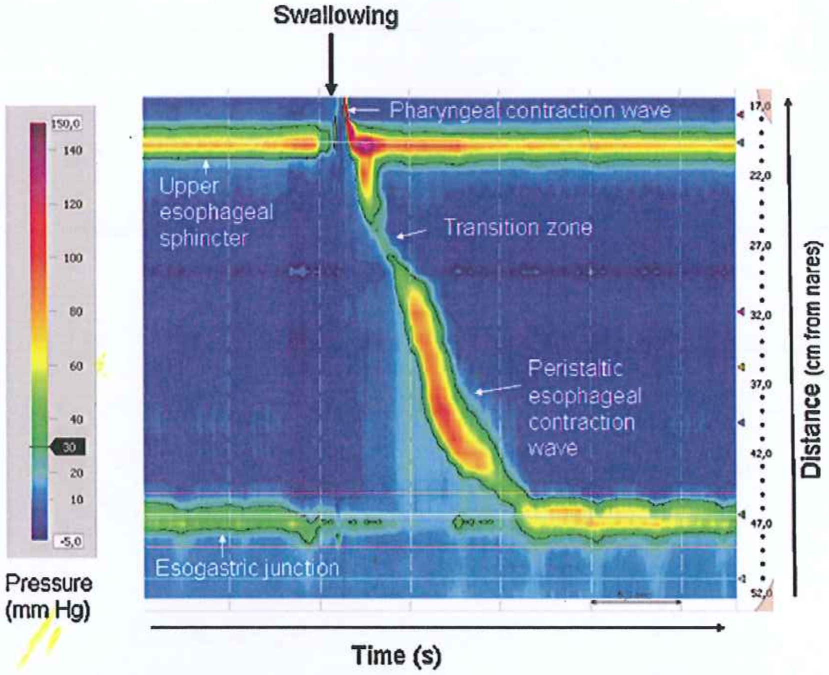


**Figure 1** Normal swallowing. Pressure activity is recorded from the pharynx to the stomach. Time is on the x-axis and distance from the nostrils is on the y-axis. Each pressure is assigned a color (left legend). Black line represents 30-mm Hg isocontour. Before swallowing, two high-pressure zones are visualized: the upper esophageal sphincter (UES) and the esogastric junction (EGJ). During swallowing, a pharyngeal contraction wave occurs and UES pressure decreases followed by peristaltic esophageal contraction wave. A transition zone separates the proximal and distal esophageal contraction waves. The EGJ relaxation starts just after swallowing.

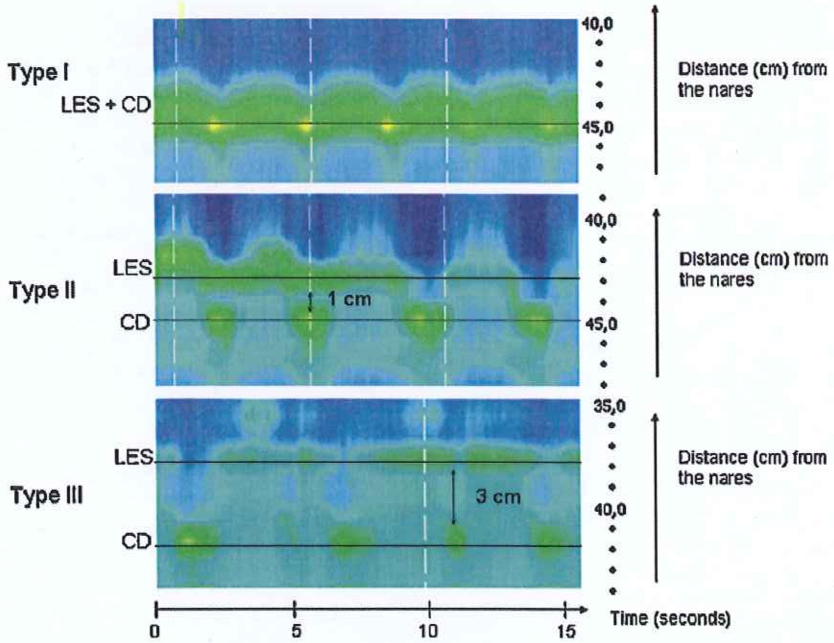


**Figure 2** The two main components of esogastric junction (EGJ) are lower esophageal sphincter (LES) and crural diaphragm (CD). When they are superimposed, the EGJ is classified as type I. When they are separated by more than 1 cm but less than 2, EGJ is type II. When LES and CD are separated by more than 2 cm, EGJ is type III. This latter defines manometric hiatal hernia.

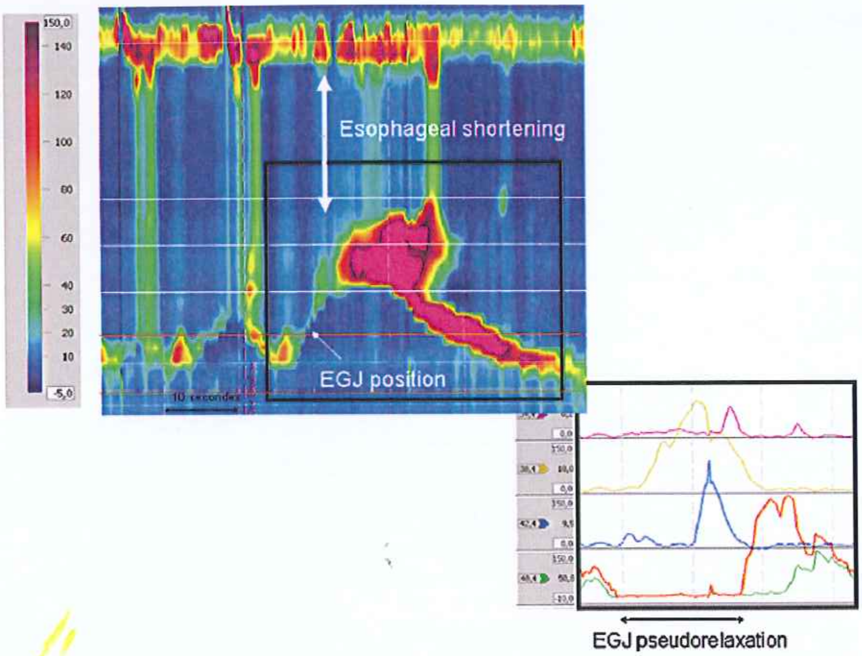


**Figure 3** On the spatiotemporal plots (left), esophageal shortening-induced elevation of esogastric junction (EGJ) is easily visualized. Line plots are represented on the right. Pressure variations are recorded in three points in the esophagus (white lines on the spatiotemporal plots). Red and green line plots represent pressure of the EGJ. The decreased pressure observed on these plots occurred when the EGJ was elevated: this is the pseudorelaxation.

esophageal sphincter (LES) are identified. A separation of these two EGJ components by more than 2 cm defines manometric hiatal hernia [4] (Fig. 2).

Esophageal HRM may also improve the accuracy and consistency of quantifying EGJ relaxation [2]. Different confounding factors can effect the quantification of deglutitive EGJ relaxation: crural diaphragm contraction during respiration, deglutitive esophageal shortening, hiatal hernia, sphincter radial asymmetry, intrabolus pressurization and recording-sensor movements from the EGJ. All these factors are clearly identified by HRM. For example, deglutitive esophageal shortening or physical movements of the catheter during the study can induce the displacement of the EGJ high-pressure zone from the recording sensor. With a conventional manometric probe, this displacement can cause "EGJ pseudorelaxation". As pressure sensors are closely distributed along the esophagus and the EGJ, HRM differentiates movement related pseudorelaxation from real EGJ relaxation [2,5] (Fig. 3).

HRM also provides a seamless dynamic representation of pressure within and across the EGJ [6]. Indeed the measurement of the esogastric pressure gradient provides an indirect study of EGJ opening and resistance as an increased gradient suggests functional obstruction at the EGJ [7] (Fig. 4).

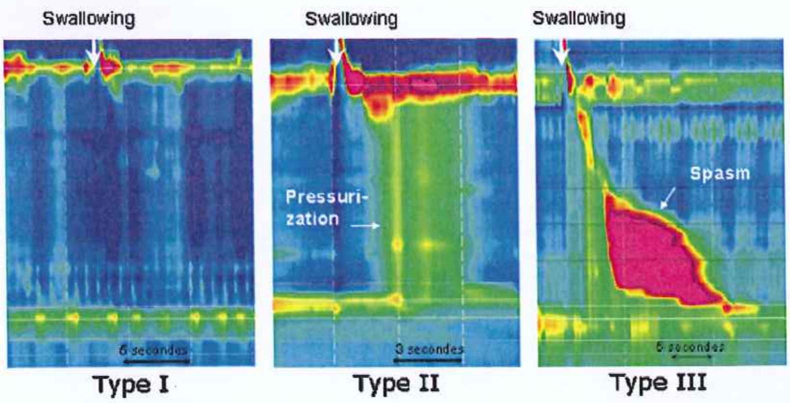


**Figure 4** Achalasia is defined by impaired esogastric junction relaxation and aperistalsis. Different subtypes are described according to topographic plot characteristics. Type I is associated with minimal esophageal pressurization. Type II is characterized by esophageal pressurization and type III is associated with spasm.

## An improved diagnostic yield for dysphagia?

According to experts the increased yield of HRM compared to conventional manometry is 12–20% in patients with dysphagia [5]. Cases that can be identified only by HRM include functional EGJ obstruction [8] as discussed above, esophageal peristaltic defects associated with proximal bolus transit abnormalities (transition zone defects [9,10]) and abnormal pharyngeal and upper esophageal sphincter (UES) function [11].

### Achalasia

HRM seems to increase the diagnostic accuracy for achalasia. Achalasia is defined by HRM with the same criteria as in conventional manometry, for example impaired EGJ relaxation and aperistalsis. Pressurization induced by esophageal shortening and true EGJ relaxation and esophageal spasm are more easily differentiated with HRM. Pandolfino et al. proposed a classification of achalasia based on topographic plot characteristics: type I associated with minimal esophageal pressurization, type II (the most frequent, about half the cases) with esophageal compression and type III with spasm [12] (Fig. 4). The classic term "vigorous achalasia" describes types II and III. The distinction between type II and type III could be clinically relevant for treatment response. Indeed type II was more likely to respond to any therapy (pneumatic dilatation, Heller myotomy, botulinum toxin) than type I (which responded better to Heller myotomy) or type III (which responded poorly to all treatments) [12].

### Focal dysmotility

HRM improves the detection of focal dysmotility because of the increased number of recording sites in the esophagus. The EPT plots also help by providing an image of esophageal functional anatomy. For example, the presence of a pressure trough between proximal and distal contraction waves represents a "transition zone" between the striated and the smooth-muscle esophagus (Fig. 1). Some authors have observed that a wider transition zone (> 2 cm) was more frequently associated with bolus stasis [5,9,13]. Others have also noted that dysphagia was associated not with the length of the transition zone but with a delayed time between the proximal and distal contraction waves [10,14]. Therefore a poor coordination of the upper and lower contraction waves could induce symptoms.

Localized disturbances of peristalsis can be more specifically assessed. Simultaneous contractions located in the mid and / or distal esophagus are sometimes associated with dysphagia and bolus escape [5]. Segmental hypotensive or hypertensive contractions can be identified. Finally a focal band of pressure within the esophagus may be a sign of focal pathology such as extrinsic compression by tumors or aberrant vasculature [5].

### Abnormal bolus transport and post-surgical dysphagia

Abnormal bolus transport can be secondary to functional EGJ obstruction, hiatal hernia or impaired peristalsis. HRM assesses the pressure gradients that dictate bolus movement. It seems to be more accurate than conventional manometry in predicting the presence of disturbed bolus transport [5]. HRM also helps distinguish rapid compartmentalized elevation of the intrabolus pressure due to ineffective contractility from impaired LES relaxation and rapidly propagated contractions (which define esophageal spasms). Multiple rapid swallows of greater than 100 mL (free drinking) increases sensitivity to detect functional or structural obstructions [15,16].

Pandolfino et al. defined the flow permissive time as the time when the bolus domain pressure exceeds the EGJ obstruction pressure [8]. A flow permissive time less than or equal to 2.5 seconds had high sensitivity and specificity (86 and 92% respectively) for predicting incomplete esophageal clearance.

Dysphagia may be present after various functional surgeries of the upper GI tract, such as Heller myotomy, antireflux surgery, or bariatric surgery such as gastric banding or bypass. Because the identification of the functional anatomy is simple with HRM, and to abnormal bolus transport can be studied, our initial experience has been extremely positive in these cases. The persistence of functional obstruction can be clearly demonstrated despite a low LES pressure after myotomy; bolus pressurization is clearly identified after antireflux surgery, and the high-pressure zones of gastric banding, diaphragm and LES can be easily separated, resulting in a better understanding of symptoms such as dysphagia or vomiting in these often complex cases (Fig. 5).

More recent technological advances have combined HRM and intraluminal impedance measurements to provide a unique visualization of both esophageal contractions and intrabolus pressures, and a perfect picture of swallowing function and its disorders [17].

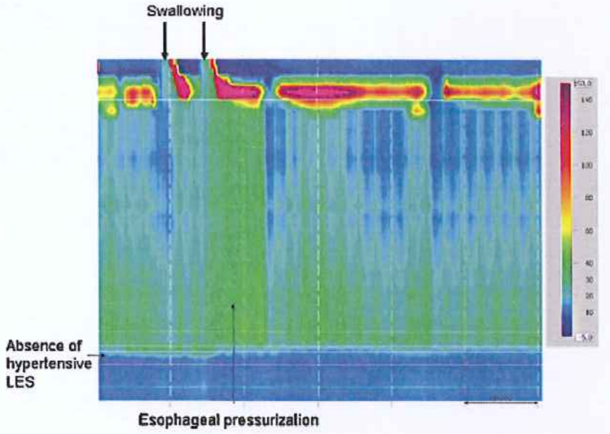


**Figure 5** In this patient with dysphagia after Nissen fundoplication, lower esophageal sphincter (LES) resting pressure is low. An aperistalsis is observed. Esophageal pressurization reflects poor esophageal clearance and functional obstruction despite the hypotensive esophagogastric junction.

### Upper dysphagia

HRM is perfectly adapted to investigate pharyngeal [18] and UES motor functions [19]. HRM combines:

- a very rapid response time necessary to study striated muscle contractions;
- an increased number of sensors necessary to overcome movement artefacts (especially pharynx elevation) during swallowing;
- circumferential pressure measurements to study UES contractile activity despite its radial asymmetry.

Normal values have been established [18,19]. Moreover, the pressure gradient measurement of EGJ, is useful to assess UES function. Indeed the position of the maximum intrabolus pressure gradient colocates precisely with obstructive pathology [11].

## Practical advantages in clinical practice

The positioning of the probe is facilitated because UES and EGJ are easily recognized. Moreover HRM doesn't require the time-consuming and poorly tolerated pull trough technique. Therefore the required procedure time is decreased. These features ensure that HRM can be performed by relatively inexperienced staff without affecting the quality of the examination.

Examinations can easily be performed in an upright and sitting position with solid-state sensors HRM as opposed to perfused manometry whose measurements are influenced by body position.

EPT plots of pressure information make it easy to identify normal and abnormal patterns of esophageal motility. Thus, the diagnosis of esophageal dysmotility should be more accurate using HRM [2,5]. The image-based evaluation is probably more adapted to human brain which is highly attuned to image recognition, than line plots. This advantage seems to suggest that manometry can be performed by less experienced operators. Indeed Grubel et al. showed that medical students provided prompt, correct diagnoses

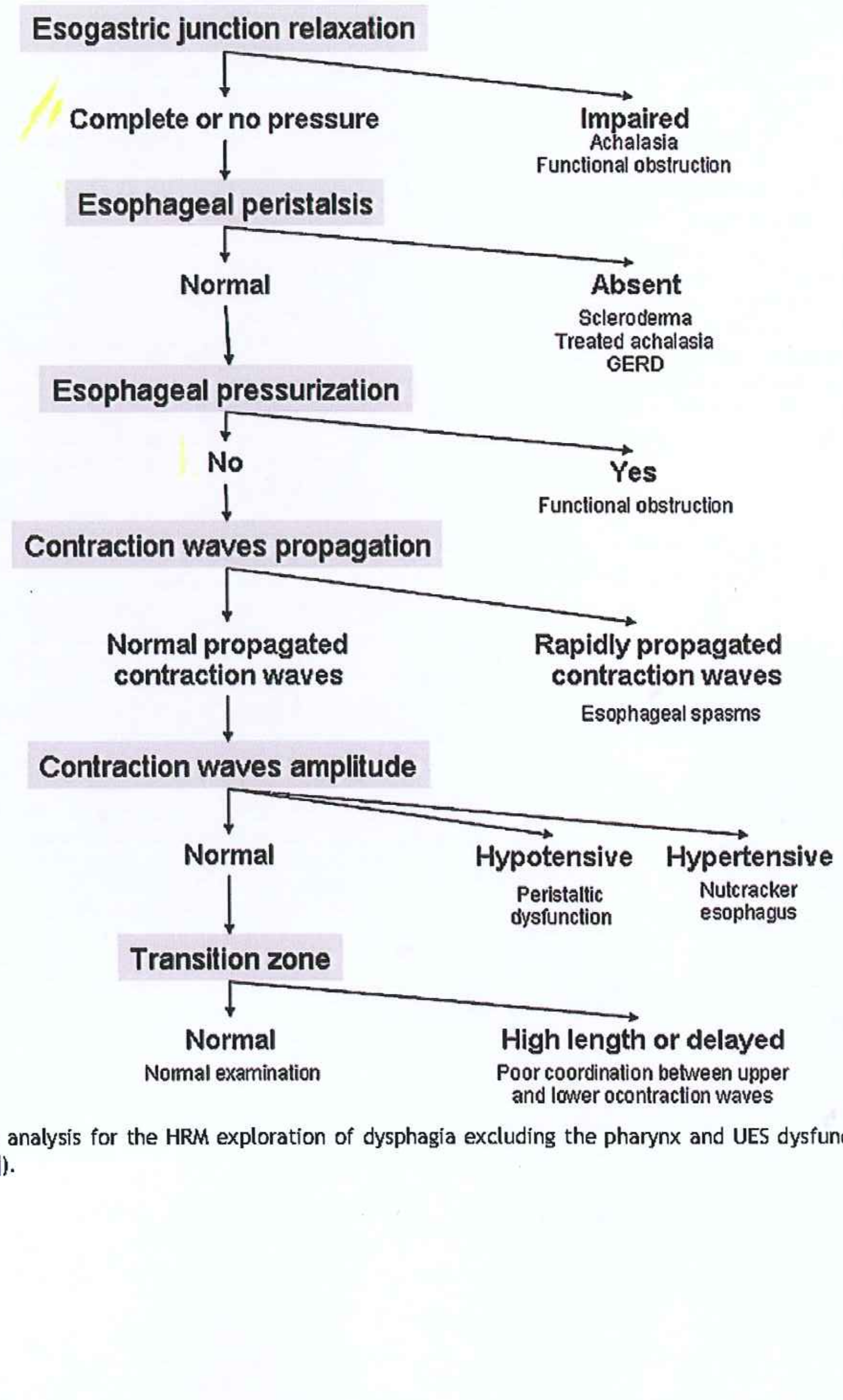


**Figure 6** Stepwise analysis for the HRM exploration of dysphagia excluding the pharynx and UES dysfunctions (modified from Pandolfino et al. [23]).

more often when manometric data were presented in the spatiotemporal format rather than line plot format [20]. Moreover, the spatiotemporal presentation was preferred by most students.

HRM may be also very useful in pediatric examination. As observed in adults, esophageal contraction waves are organized into two segments [21]. Even in crying children, UES and LESs are easily recognized as well as swallow induced esophageal contractions. Our initial experience suggests that the examination time is clearly reduced.

## Esophageal high-resolution manometry: a new gold standard?

HRM is an essential tool for mechanistic studies of esophageal function in research. Transient LES relaxations (tLESr), the most important mechanism of gastroesophageal reflux disease, are easily identified. Pandolfino et al. used HRM to demonstrate that esophageal shortening and crural diaphragm inhibition always preceded EGJ opening and common cavity in case of tLESr [22]. Moreover, the effects of pharmacological agents on different esophageal segments were clarified thanks to HRM [9,23].

In clinical practice, HRM should replace conventional manometry. First of all HRM is easy to perform and probably more reproducible. Second, HRM predicts abnormal bolus transport more accurately than conventional manometry [5]. Third, not only is the diagnostic agreement between conventional and HRM high [2] but some publications also emphasize that clinically important pathologies (impaired EGJ relaxation, achalasia, distal esophageal spasm, localized abnormality of peristalsis) can only be detected by HRM [2,5]. A classification of esophageal motility disorders based on pressure topography characteristics has been proposed by the Chicago group [24]. Stepwise analysis is considered for the exploration of dysphagia:

- EGJ relaxation;
- the presence and propagation of esophageal peristalsis;
- the build-up of intrabolus pressure within the esophagus;
- contractile vigor (Fig. 6).

These are no longer unspecific disorders.

However, the widespread use of HRM may be limited because the equipment is expensive. Moreover the clinical significance of HRM-detected esophageal dysmotility remains uncertain in some cases. A better assessment of EGJ and esophageal body motility could identify diagnosed abnormalities with no clinical expression. A prospective evaluation of the correlation between symptoms and HRM-detected abnormalities (such as wide transition zone) are needed.

In conclusion, despite these limitations, HRM is an important advance in the assessment of esophageal and esogastric function. It provides benefits in research and clinical practice, is fast becoming the gold standard to study esophageal and esogastric motility.

## Conflict of interest

None.

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