The technical aspects, interpretation of data, and clinical application of high-resolution esophageal manometry


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Aims — the objective of the present article was to describe the methodology of high-resolution esophageal manometry and analysis of its results in the context of their conformity with the requirements of the modern internationally accepted guidelines. Another objective was to demonstrate the clinical significance of investigations into the motor function of the oesophagus for making the diagnosis of oesophageal disorders, their differential diagnostics, and the choice of the adequate treatment strategies in the patients presenting with these conditions.

Basic premises. Pathogenesis of many oesophageal problems is associated with the disturbances of the motor function of the thoracic oesophagus and/or the lower oesophageal sphincter (LES). High-resolution esophageal manometry makes it possible to measure resting pressure at the level of the upper and lower oesophageal sphincters, to estimate the degree of their opening in response to swallowing, to evaluate the force of muscular contraction in the thoracic oesophagus, to determine the location of the upper and lower oesophageal sphincters (i.e. their distance from the nostrils) as well as the total length of the oesophagus. Moreover, high-resolution manometry permits to detect the gastroesophageal hernia and determine its size, reveal spastic contractions, estimate the effectiveness of esophageal motility, and discover a barrier preventing the bolus passage at the level of sphincters. The evaluation of changes in oesophageal motility is of primary importance for differential diagnostics in the patients suffering from dysphagia and non-coronarogenic chest pain, achalasia cardiae, other organic and functional diseases of the oesophagus as well as for taking decision as regards the necessity of endoscopic or surgical intervention for the treatment of gastroesophageal reflux diseases and achalasia cardiae.

Conclusion. High-resolution esophageal manometry should be recommended for the management of the patients presenting with the clinical symptoms suggesting possible disturbances of the motor function in the thoracic oesophagus (such as dysphagia retrosternal pain, regurgitation, and belching). Of special importance is the evaluation of the motor function of the oesophagus for taking the final decision as regards the necessity of endoscopic or surgical intervention for the treatment of gastroesophageal reflux diseases and achalasia cardiae. At present, high-resolution esophageal manometry is considered to be «the golden standard» in diagnostics of the disturbances in the motor function of the oesophagus.

Keywords: high-resolution esophageal manometry of the oesophagus, achalasia cardiae, gastroesophageal reflux diseases, fundoplication.

There is no conflict of interests

Esophageal motility disorders can be an underlying mechanism of the pathogenesis of many esophageal disorders, such as gastroesophageal reflux disease (GERD), achalasia. In other diseases (scleroderma systematica, eosinophilic esophagitis), the motility disorders are consequences of structural changes in the esophageal wall and LES.

The potential of this modern and high-tech tool includes measurement of the upper and lower esophageal sphincters resting pressure (LES, UES), LES and UES relaxation during swallowing, a vigor of esophageal contractions, a position of upper and lower esophageal sphincters (a distance from nostrils), and a length of the esophagus. The esophageal manometry helps to identify the hiatal hernia (HH) and its exact dimensions, premature (spastic) contractions or ineffective contractions of the esophageal body and any obstacle for a bolus passing through sphincters [1].

The esophageal manometry is indicated in patients with such clinical symptoms as dysphagia, noncardiac chest pain, regurgitation, etc. The evaluation of esophageal motility is paramount at making a decision towards possible and required surgical treatment of GERD and achalasia.

History of the method

The esophageal motor function studies (a so-called conventional manometry) were first performed as early as in 1940s—1950s using an intravesophageal balloon filled with water or gas introduced into the lumen of the organ. However, this procedure had significant restrictions due to an extremely slow response and low sensitivity of the registering system to changes in the intravesophageal pressure, as well as due to the effect of the balloon on esophageal motility. In 1970s, W. Dodds and R. Arndorfer [2, 3]
developed a brand new system for esophageal pressure measurement: water-perfused manometry with a catheter consisting of the capillary tubes system fed with water by an external pump. The advantages of the water-perfused manometry included a significantly higher sensitivity (as compared to the balloon) and registration of peristalsis at several points along the esophagus. The disadvantages included a small number of channels in the catheter located distant from each other (not less than 5 cm), as well as the method laboriousness and a low accuracy of the findings obtained for pressure measurement in the LES area due to a proximal dislocation of the sphincter associated with peristaltic wave after swallowing.

In 1977, the Dent [4] sleeve sensor catheter was introduced, in which a 6-cm sleeve sensor was added to continuously measure the LES pressure. The sleeve eliminated the LES dislocation and carry out more exact measurements shown on the screen as several two-dimensional curves (Y-axis: pressure; X-axis: time). The curve analysis allowed evaluation of the resting LES pressure and residual LES pressure, and the amplitude of contractions of the thoracic esophagus; diagnosis of spastic contractions and no contractions in the body of the esophagus during swallowing [1, 4].

Attempts to optimize the test methods for esophageal motility disorders were also made in Russia. In 1970-1980-s, V.Kh. Vasilenko and A.L. Grebenev [5] used a probe with several small-diameter balloons thus avoiding an excessive stimulation of the esophagus and secondary contractions of its wall.

S.A. Chernyakevich [5, 6] contributed greatly to the development of esophageal functional diagnostic techniques in this country; she developed a brand new test method, ionomanometry, using a combined specific probe (Istok-system, Fryazino) which contained two open manometric catheters in addition to pH sensors. The distance between the catheters was 5 cm. The method technique was to introduce a probe from the stomach into the esophagus at a 1—0.5 cm interval and record pressure changes in different parts of the esophagus. A combination of pH-metry and manometry within a single study permitted to identify esophageal motility disorders, structural abnormalities of the LES (axial hiatal hernia) and gastroesophageal reflux at the same time.

In 1990-s, R. Clouse et al. [7] developed a new system for pressure measurements characterized by a reduced distance between sensors (from 3—5 to 1 cm) and an increased number of sensors on the catheter from the pharynx to the esophagus (up to 36). This approach facilitated simultaneous evaluation of the upper esophageal sphincter, esophageal and LES motor function altogether. An addition of one more axis became a significant improvement of the procedure; it evaluated pressure changes in topography instead of a conventional two-dimensional plane (Y-axis: contraction vigor, X-axis: time). The topographic approach to data presentation when higher pressure values are depicted in colours of the red-brown spectrum and lower pressure values are depicted in blue resulted in a pictorial and easy for the analysis and interpretation presentation of the esophageal contractile function (Figure 1) [8].

The main advantages of the high-resolution manometry are accurate calculations, a simple procedure, and an illustrative method. During the study, the software synthesizes an integral picture of the esophageal motility so that a real-time 3D image of the esophageal functional anatomy is shown on the screen.

In order to standardize the test procedure, data analysis, and systematization of nosologies, the 2008 San Diego (USA) consensus of experts in esophageal manometry generated the Classification of Esophageal Motility Disorders. Later, such consensuses were held in Ascona (Switzerland) in 2011 and in Chicago (USA) in 2014. Results of the recent consensus The Chicago Classification of Es-

*Figure 1. High-resolution manometry: normal esophageal motility.*
Интенсивность ввиду отсутствия жалоб или кровотечений из верхних отделов пищеварительного тракта.

**Main indications and contraindications for the esophageal manometry, as well as stages of the high-resolution esophageal manometry interpretation in accordance with the current Chicago Classification of Esophageal Motility Disorders are listed below [9—11].**

**The esophageal high-resolution manometry is indicated:**
- in dysphagia after ruling out the organic obstruction: diagnosis of distal esophageal spasm, achalasia, and ineffective esophageal motility;
- in non-cardiac chest pain: diagnosis of distal esophageal spasm, hypercontractile esophagus, achalasia, HH;
- in preoperative examination of patients with achalasia (to confirm the diagnosis and specify the achalasia type);
- in preoperative examination of GERD patients in whom anti-reflux surgery is scheduled (to rule out the ineffective esophageal motility and achalasia and to specify the HH dimensions);
- in preoperative examination of patients with obesity in whom bariatric surgery is scheduled;
- to determine the surgical treatment efficacy of achalasia and GERD;
- to determine the LES position before the pH-metry or impedance pH-metry;
- in dysphagia after anti-reflux surgery;
- to determine exact dimensions of the HH.

**The esophageal manometry is not performed in cases, when any invasive probe diagnostic manipulations are contraindicated:**
- esophageal and gastric malignancies;
- esophageal and gastric ulcers with a risk of bleeding;
- II—IV degree esophageal varices;
- recent (less than 3 months) surgical interventions or bleeding from the upper gastrointestinal tract;
- burns, diverticula, decompenсated esophageal strictures;
- persistent cough or vomiting;
- aortic aneurysm;
- severe essential hypertension;
- obstruction of the nasopharynx;
- maxillofacial trauma;
- severe coagulopathies;
- mental disorders.

The high-resolution esophageal manometry include the following stages:
1. Preparation for the study; catheter calibration (for the water-perfused system);
2. Introduction of a catheter into the esophagus and its placement at a required depth;
3. Per protocol study according to the Chicago Classification;
4. Interpretation of results;
5. Drawing a conclusion.

**High-Resolution Manometry Study**

The esophageal motility study is performed in the supine position (in order to exclude the effect of the gravity force on the fluid pressure in capillaries of a water-perfused catheter and on the esophageal motility) with assessment of the LES resting pressure and peristalsis of the esophageal body after administering ten 5 mL water swallows (according to the Chicago Classification). The interval between swallows should be not less than 30 seconds [9].

After catheter calibration and the application of a topical anesthetic to the patient’s naris and/or throat, the HRM catheter is placed transnasally and positioned with the pressure sensors spanning a length extending from the hypopharynx, through the esophagus, to 3 to 5 cm within the stomach. After a brief period to allow patient acclimation, a baseline of resting pressures can be obtained during approximately 30 seconds of easy breathing without swallows. Correct catheter placement to traverse the esophago gastric junction can be confirmed during this period by recognition of the presence of the pressure inversion point, which is the point at which the inspiration-associated negative intrathoracic pressure inverts to the positive intra-abdominal pressure. Having the patient take deep breaths facilitates identification of the pressure inversion point by augmenting the EGJ pressure and exaggerating the intrathoracic and intra-abdominal pressures [10].

In addition to the standard protocol, many investigators assume further diagnostic tests (outside the Chicago Classification) such as solid food swallowing (boiled rice, dry cracker) and multiple rapid swallow test (5 swallows of 2 mL of fluid each at a 2—3 s interval) to assess latent disorders and the spare capacity of the esophageal motor function more properly [11—16].

**Interpretation of Esophageal Pressure Topography**

HRM studies can be interpreted in a stepwise, hierarchical fashion directed by the Chicago Classification. The evaluation scheme is intended only for patients without prior surgery affecting the esophagus or the esophagogastric junction [9]. It is important that the absolute values reported in the Chicago Classification are based on normative values generated with the Sierra HRM assembly (Given Imaging) from supine swallows of 5 mL of water. Thus, the interpretation of manometry studies performed using different catheter assemblies, patient
positions, and/or boluses (volume and/or consistency) requires the recognition of expected differences in the normative values of HRM metrics [10]. The evaluation scheme consist of Esophagogastric Junction resting pressure and Individual Swallow Assessment.

Although not incorporated in the Chicago Classification of esophageal motility diagnoses, esophago-gastric junction (EGJ) morphology and basal pressure should be assessed with HRM. The basal EGJ pressure should be assessed during a period of quiet breathing without swallows [10].

At rest, (‘resting’ landmark recording is measured during an episode in which the patient does not swallow and breathe normally) 2 high-pressure areas are distinguished in contour plots; the Chicago Classification call these areas the resting pressure. In addition, pressure changes in functionally different parts of the esophagus related to pressure changes in the thoracic and abdominal cavities may be observed depending on the respiration phase (Figure 2):

— at inspiration, the pressure in the thoracic cavity decreases (negative pressure), the EGJ is dislocated towards the stomach due to contraction of diaphragm crura; at that, the pressure in the esophago-gastric junction increases [10];
— at expiration, the pressure in the thoracic cavity is increased, and the EGJ area is shifted proximad.

The analysis of contour plots at rest include the assessment of the following parameters:

— EGJ tone (basal pressure, resting pressure) during expiration and inspiration;
— EGJ morphology.

The following changes in the EGJ resting pressure may be found during the study:

— A decrease in the EGJ tone (Figure 3). As a rule, these changes are typical for patients with GERD or sys-

Figure 2. Resting pressure.

Figure 3. A decrease in the EGJ tone.
temic diseases of the connective tissue and diabetes mellitus [11]:

— An increase in the EGJ tone above. It is most common among patients with achalasia and hypercontractile esophagus (Figure 4).

With HRM and Clouse plots, the relative localization of the two contractile elements of the EGJ, the LES and the crural diaphragm (CD) can be distinguished. According the Chicago Classification there are three types of EGJ morphology [9]:

— **Type 1** (normal): Complete overlap of CD and LES components with single peak on the spatial pressure variation plot (Figure 5);

— **Type 2** (within normal): LES and CD are spatially separated such that there is a double-peaked pressure profile on the spatial pressure variation plot at inspiration, but the nadir pressure between peaks does not decline to gastric pressure and the separation between the LES and CD peaks is 1—2 cm (Figure 6);

— **Type 3** (hiatal hernia): the inspiratory spatial pressure variation plot exhibits >2 cm separation between the LES and CD peaks with the nadir pressure between them equal to or less than gastric pressure (Figure 7).

After evaluation basal EGJ, esophageal motility is examined in Individual Swallow Assessment. The esophageal manometry evaluates the deglutitive LES relaxation and esophageal body contractility and/or peristalsis during each swallow.

The analysis of each swallow starting with assessment of the LES relaxation using a specific integral parameter, **integrated relaxation pressure** (IRP). IRP is the mean pressure of the EGJ during the 4 contiguous or noncontiguous seconds of maximal relaxation (ie, lowest pressure) in the deglutitive window (10 seconds after the
swallow). IRP is dependent from gastric pressure, therefore, it is better to place the gastric reference 2 cm below the EGJ. Normal IRP usually does not exceed 15 mmHg [9]. The increased IRP demonstrates a functional (achalasia) or structural (stricture, tumour) EGJ obstruction (Figures 21—26).

After the IRP analysis, the contraction vigor of the esophagus after swallowing 5 mL of fluid is assessed. For this purpose, another integral parameter, a distal contractile integral (DCI) was introduced; it reflected both the contraction vigor and rate of the smooth muscle. This parameter is measured as a multiplication of the amplitude, length and duration of the contraction (mmHg·cm·sec) [9].

Depending on the contraction vigor, the Chicago Classification, v.3, subdivides contractions into the following types [9, 18, 19]:

— **Normal**: DCI >450 mm Hg·cm·s but <8000 mm Hg·cm·s (Figure 8);
— **Hypercontractile**: DCI >8000 mm Hg·cm·s. The contraction becomes extremely intensive and is accompanied by a marked retrosternal pain (Figure 9);
— **Ineffective**: depending on the DCI reduction, ineffective contractions are subdivided into failed contractions (DCI <100 mm Hg·cm·s) (Figure 10) and weak contractions (100 < DCI < 450 mm Hg·cm·s) (Figure 11).

If no pathology was found after the analysis of peristaltic contraction vigor, the next stage of the hierarchical analysis, a contraction pattern analysis, began.

Normally, the peristaltic contraction spreads from the UES distad gradually (Figure 12). Starting from the cross-striated muscles of the proximal esophagus (segment S1), passing a transitional zone (TZ) where peristaltic contractions are absent due to the transition of cross-striated muscles into smooth muscles, a contraction reaches the smooth-muscle part of the esophagus (segments S2 and S3). In the distal esophagus, contractions decelerate, propagation velocity slows signifying the termination of esophageal peristalsis and the onset of ampullary emptying (segment S4), which is mechanistically very distinct, amounting to the reconstitution of the contracted LES [9].

However, esophageal contractions do not always follow the described algorithm; sometimes contractions of the smooth muscle part of the esophagus begin prematurely, accompanied by quite severe retrosternal pain, impaired peristalsis of the esophagus, and dysphagia. The emergence of large breaks in the peristaltic wave is an-
Figure 8. Contractile vigor: normal (450 < DCI < 8000 mm Hg·cm·s).

Figure 9. Contractile vigor: hypercontractile (DCI > 8000 mm Hg·cm·s).

Figure 10. Contractile vigor: failed (DCI <100 mm Hg·cm·s).
other disorder of the contraction pattern which may lead to the impairment of esophageal clearance.

The following parameters are used in analysis of the esophageal contraction pattern (Figure 13): contractile deceleration point (CDP), largest break, and distal latency (DL) [9].

The contractile deceleration point (CDP) — is a key landmark in the assessment of the contraction pattern. On Clouse plots, the CDP represents the inflexion point in the contractile front propagation velocity (Figure 14). CDP indicating the transition from peristalsis to ampullary emptying is localized in the distal esophagus. If it is difficult to find the contractile deceleration point (in the case of an atypical peristaltic wave), the below rule should be followed: CDP must be localized to within 3 cm of the EGJ [9].

In the case of ineffective esophageal motility when the vigor of the distal esophagus contractions is reduced, the CDP is measured on a 20 mm Hg isobar (Figure 15). In the case of excessively vigorous contractions, the CDP is determined at 50 mm Hg. In instances of compartmentalized pressurization the CDP needs to be localized along an isobaric contour line of greater magnitude than the compartmentalized intrabolus pressure (Figure 16) [9].

A correct determination of the CDP is crucial, because it permits to calculate the duration of the distal latency (DL).

The distal latency (DL) is measured from upper sphincter relaxation to the contractile deceleration point. Normal DL duration is not less than 4.5 s (Figures 13, 15, 16). This parameter was introduced into the analysis in order to detect premature contractions occurred at the
Figure 13. Key metrics of pressure topography plots used to describe peristalsis in the Chicago Classification.

Figure 14. The contractile deceleration point at a 30 mmHg isobar.

Figure 15. The CDP determination at a 20 mmHg isobar in the case of ineffective esophageal motility.
distal esophagospasm or type III achalasia. Pathophysiological explanation of premature contractions states the dysfunction (or death) of inhibitory neurons in the intramural nerve (Auerbach’s) plexus [9, 12].

**The largest break** is a zone on the peristaltic wave, where contractions of the muscular esophageal wall are absent or occur with an amplitude of less than 20 mm Hg (breaks in the 20-mm Hg isobaric contour). Normally, the length of the largest break does not exceed 5 cm (Figures 17 and 19) [9].

In swallows with a normal DCI, the integrity of the peristaltic wave is assessed by measuring the length of axial breaks in the 20-mm Hg isobaric contour (largest breaks) [10]. Depending on the DL interval and the largest break, the Chicago Classification v.3 subdivides contractions with normal DCI (450 < DCI < 8000 mm Hg × cm × s) into the following contraction patterns [9, 17]:

- **Intact:** DL >4.5 s; the largest break is less than 5 cm (Figure 17);
- **Premature:** DL <4.5 s (Figure 18);
- **Fragmented:** Large break (>5 cm length) in the 20 mm Hg isobaric contour with DCI >450 mm Hg·cm·s (Figure 19).

It should be noted that contractions with DCI < 450 mm Hg·cm·s cannot be analysed according to contraction pattern because they are ineffective.

**Figure 16.** The CDP determination at a 50 mmHg isobar in the case of compartmentalized pressurization.

**Figure 17.** Contraction pattern: intact (DL > 4.5 s, there is no break; 450 < DCI < 8000 mm Hg·cm·s).
An assessment of intrabolus pressure is the next stage of analysis. In normal peristalsis of the esophagus, the intrabolus pressure (IBP) should exceed the intragastric one (to ensure normal antegrade propulsion of a food lump), but it should be not more than 30 mmHg.

If bolus transit is impeded by any obstruction and esophageal peristalsis is preserved, the intrabolus pressure rises.

According to the Chicago Classification v.3, there are several types of intrabolus pressure pattern [9, 12]:

- **The panesophageal pressurization**: an increase in the intrabolus pressure (more than 30 mmHg) extending from the UES to the EGJ. The panesophageal pressurization is most common in the type 2 achalasia (Figure 20);

- **Compartmentalized pressurization**: pressurization of >30 mm Hg extending from the contractile front to the EGJ. These manometric features are observed at a mechanical EGJ obstruction (stricture, hernia) or achalasia onset with the preserved contractile activity of the esophagus (Figure 21);
— **EGJ pressurization:** pressurization restricted to zone between the LES and CD in conjunction with LES-CD separation in the case of HH (Figure 22);
— **Normal:** no bolus pressurization >30 mm Hg.

Based on the information from the individual swallows, a hierarchical categorization of motility disorders is made. First the LES function, and subsequently the esophageal pressure patterns are used to classify the patient and make a diagnosis.

**The Chicago Classification: Esophageal Motility Diagnosis**

The Chicago Classification subdivides all possible conditions of the esophageal motility into 4 large groups [9]:
— Disorders with EGJ outflow obstruction;
— Major disorders of peristalsis;
— Minor disorders of peristalsis;
— Normal esophageal motility.

**Disorders with EGJ outflow obstruction**

According to the analysis algorithm recommended by the Chicago Classification, the integrated relaxation pressure (IRP) is the first estimated parameter. Impaired EGJ relaxation with elevation IRP >15 mm Hg is observed in several types of disorders (Figure 27) united under a common name **Disorders with EGJ outflow obstruction** [9, 19]:

**Achalasia**

Among primary esophageal motility disorders, achalasia (from a Greek word meaning «lack of relaxation») is...
the most important. A degenerative process that selectively affects the excitatory and inhibitory neurons ensuring the contraction and relaxation of the esophageal smooth muscles is the basis of the achalasia pathogenesis. A diagnosis of achalasia requires both impaired deglutitive EGJ relaxation and absent peristalsis. However, absent peristalsis is not synonymous with absent pressurization or contractility.

Depending on pressurization patterns and presence of spastic contractions the Chicago Classification v.3 distinguishes three main types of achalasia [9]:

— **Type I achalasia** (classic achalasia): elevated median IRP (>15 mm Hg), 100% failed peristalsis (DCI < 100 mm Hg·cm·s) (Figure 23);

— **Type II achalasia** (with esophageal compression): elevated median IRP (>15 mm Hg), 100% failed peristalsis, panesophageal pressurization with >20% of swallows (Figure 24);

— **Type III achalasia** (spastic achalasia): elevated median IRP (>15 mm Hg), no normal peristalsis, premature (spastic) contractions with DCI > 450 mm Hg·cm·s with >20% of swallows (Figure 25).

There is a hypothesis that these 3 types of esophageal motility disorders described based on the esophageal manometry findings and observed in patients with achalasia are not three different forms of the disease, but successive stages of achalasia progression. It is believed that at the initial stage of the disease (which occurs with the gradual death of inhibitory motor neurons), motility changes like spastic achalasia (type III) are observed; then, as the excitatory neurons die and the contractile function of the esophagus is depressed, type II achalasia is observed. In
case of the total death of motor neurons of the intramural nerve (Auerbach’s) plexus, motility changes described as type I achalasia occur accompanied by a significant dilation of the esophagus and its S-shaped deformation [20].

**Esophagogastric Junction Outflow Obstruction**

The conclusion «EGJ outflow obstruction» is made when the HRM findings do not completely meet achalasia criteria: incomplete LES relaxation (IRP > 15 mm Hg) combined with preserved peristalsis (Figure 26).

If the EGJ obstruction is ruled out, the next stage of the hierarchal algorithm begins: assessment of vigor and pattern of peristaltic contractions. In accordance with the Chicago Classification, peristaltic disorders are subdivided into 2 large subgroups [9]:

— Major disorders of peristalsis;
— Minor disorders of peristalsis.

**Major disorders of peristalsis**

Major disorders of peristalsis are not encountered in control subjects; they are related to significant changes in the distal latency (DL) and distal contractile integral (DCI) with normal values of the integral relaxation pressure (IRP); they occur with obvious clinical symptoms and include the following types (Figure 30) [9]:

— **Distal esophageal spasm (DES):** normal median IRP, ≥20% premature contractions with DCI >450 mm Hg·cm·s. During DES time between the onset of the UES relaxation and the arrival of the peristaltic wave in the distal esophagus is too short (DL<4.5 s). Some normal peristalsis may be present (Figure 18);

— **Hypercontractile esophagus:** normal median IRP, at least two swallows with DCI >8000 mm Hg·cm·s, hypercontractility may involve LES (Figure 28);
— **Absent contractility**: normal median IRP, 100% failed peristalsis (Figure 29).

Hypercontractile esophagus usually also have spastic characteristics such as multipeaks, repetitive patterns and short distal latency. A DCI $\geq$ 8000 mm Hg·cm·s was found to be associated with chest pain and dysphagia and with positive response to achalasia treatment.

Absent contractility can be seen in patients with systemic sclerosis and predisposes patients to gastroesophageal reflux disease. Absent contractility is clinically important in patients that are considered for fundoplication or gastric bypass surgery. In patients with absent contractility, these surgical interventions are contra-indicated because a higher chance of post-surgical dysphagia is expected.

**Minor disorders of peristalsis**

Minor disorders of peristalsis may be found during the HRM in asymptomatic patients as an accidental finding. They are characterized by decreased vigor (DCI < 450 mm Hg·cm·s) or disorder of contraction pattern (largest break > 5 cm).

Minor disorders of peristalsis have a clinical relevance for GERD patients, because in most cases they...
Minor disorders of peristalsis include the following types (Figure 32) [9]:

— **Ineffective esophageal motility:** ≥50% ineffective (DCI < 450 mm Hg·cm·s) swallows with normal IRP mean values (<15 mm Hg) (Figure 31);

— **Fragmented peristalsis:** ≥50% fragmented swallows (largest break > 5 cm) with normal values of DCI > 450 mm Hg·cm·s and IRP < 15 mm Hg (Figure 19).

Ineffective esophageal motility often accompanied by a low LES pressure. Ineffective esophageal motility and low LES pressure were found to be more prevalent in patients with gastroesophageal reflux disease. However, the predictive value of these findings to predict reflux dis-
ease is insufficient. As with absent contractility, it is only clinically important in patients in evaluation for antireflux surgery.

In order to assess the peristaltic capacity in ineffective esophageal motility and fragmented peristalsis, it is recommended to carry out *adjunctive tests*: the multiple rapid swallow test (MRS), solid bolus swallows, rapid drink challenge test, multiple water swallows and others [13—16].

Multiple rapid swallowing (small volume (5—10 ml) ingested in series of 5 swallows) stimulates neural inhibition resulting in abolition of contractions in the esophageal body and complete lower esophageal sphincter relaxation which is followed by peristalsis and LES contraction. It has been suggested that multiple rapid swallowing able to detect abnormalities in inhibitory or excitatory esophageal mechanisms in patients with esophageal symptoms and either normal HRM or ineffective esophageal motility. Healthy subjects had complete inhibition of esophageal body motility during MRS and a strong motor response after MRS, i.e. amplitude of esophageal body contractions in the esophageal body and LES tone being higher than after single swallows (Figure 33).

The absence of strong peristaltic contraction after a series of swallows demonstrates a significant reduction of the peristaltic capacity. Almost 50% patients with ineffective esophageal motility have abnormal MRS, mainly consistent on inability to increase amplitude of esophageal body contraction after MRS (Figure 34) [13—17]. So, WRS test permit to detect impaired peristaltic response in hypotensive dysmotility.

The multiple rapid swallow test also permits to identify defective inhibition in hypertensive dysmotility: failure to suppress contractility during repeated swallows (Figure 35) [13—17].

**Figure 31.** Ineffective esophageal motility in a GERD patient (DCI =326 mm Hg-cm-s).

**Figure 32.** Hierarchical algorithm for the interpretation of HRM studies with CC v3.0: minor disorders of peristalsis [9].

**Figure 33.** The multiple rapid swallow test, normal values.
Normal esophageal motility

A normal esophageal motility (Figure 36) is defined by the following manometric criteria according to the Chicago Classification [9]:
- No EGJ outflow obstruction (IRP is normal);
- More than 50% of swallows are effective (DCI > 450 mm Hg·cm·s, largest break <5 cm);
- The number of abnormal (premature, failed or hypercontractile) contractions does not exceed 20%.

Data interpretation depending on the device, catheter, and patient’s position during the study

Normal limits of manometric parameters (according to the Chicago Classification) are relatively conventional because they are based on tests carried out using the Sierra Scientific Instruments apparatus with solid-state catheters (4.2 mm in diameter) with 36 sensors positioned not more than 1 cm apart. Values within the range of 5—95 percentile were considered normal [9, 21—23].

At the same time, the Chicago Classification emphasizes that results of the high-resolution esophageal manometry significantly depend on the apparatus, catheter type (water-perfused, solid-state), its diameter, distance between pressure sensors on the catheter, patient’s weight, age, and race, patient’s position during the study and many other conditions. However, the limits of the Chicago Classification are developed without taking into account the catheter type and do not reflect these differ-

Figure 34. The multiple rapid swallow test in ineffective esophageal motility.

Figure 35. The multiple rapid swallow test: defective inhibition.
ences; in many publications [24—26] dedicated to determination of normal limits in the esophageal manometry, DCI and IRP parameters in the group of healthy volunteers are significantly lower than those of the current Chicago Classification.

In addition, studies comparing manometric parameters obtained in tests using a solid-state or water-perfused catheter demonstrated that whereas DL and DCI values almost do not depend on the catheter type, LES and UES resting pressure values differ significantly when solid-state and water-perfused catheters are used [27—30]. It is related to different diameters of the catheters, a higher record rate and circular location of pressure sensors on the solid-state catheter.

Several studies with water-perfused catheters in patients with verified achalasia demonstrated that IRP > 15 mm Hg accepted by the Chicago Classification as the upper limit of normal were not always adequate for water-perfused catheters: in 50% patients with achalasia, the IRP was lower than 15 mm Hg [29]. M. Zavala-Solares et al. [28], G. Capovilla et al. [25] also confirmed that results of IRP, DCI, and UES resting pressure obtained with a water-perfused catheter was usually lower than similar parameters obtained with a solid-state catheter.

Thus, when using the standards specified in the Chicago Classification, it is necessary to interpret the results obtained using the water-perfusion systems with care (taking into account clinical data and data from other test methods) [18].

When analyzing the esophagus manometry results, the position of the patient during the study is also important. The esophageal manometry standards available today are designed for the supine position. This is due to the fact that the supine position of the patient neutralizes the gravity effects on a bolus transit through the esophagus. In addition, the water-perfused catheters do not allow patient’s vertical position due to the gravity effects on fluid pressure in the catheter capillaries.

At the same time, the vertical position during the study is physiological and minimizes the effects of transfer aortic pulsation on the esophageal manometry (this is especially important in the diagnosis of esophago-gastric junction outflow obstruction) [31]. Several studies have shown that moving a patient to a vertical position often leads to ruling out of the diagnosed «ineffective esophageal motility» obtained in the supine position [32, 33]. In a number of studies, it was possible to detect a decrease in DCI, DL, IRP values in the vertical position of patients [33—35]. Today, in many European and US centres, where solid-state catheters are used for diagnostics, patient’s semi-sitting position is most common (with an upper part of the body elevated by 30 degrees) during the study [36].

In the Russian Federation, in accordance with The First Russian Consensus in the High-Resolution Esophageal Manometry adopted on November 11, 2017, it is recommended to study the esophageal motility function in the supine position with the upper body elevated by 15 degrees (to exclude choking over and aspiration during swallowing).

Among researchers involved in the esophageal manometry, the use of various types of bolus (solid, viscous) is also actively discussed to increase the diagnostic value of the study. In the investigations available to date [31, 34, 37] it is shown that a solid bolus leads to a significant increase in DCI, IRP values, which is a kind of a provoking factor that makes it possible to identify esophageal motility disorders more exactly. However, when using a solid and viscous bolus, there are difficulties in standardizing
the amount, volume of the bolus, and type of the product used (bread, cracker, marshmallow). In this connection, further studies are required to introduce these techniques into clinical practice.

**Conclusion**

The high-resolution manometry is a modern tool of functional diagnostics that objectifies the pathogenetic mechanisms of dysphagia, retrosternal pain, heartburn, belching, regurgitation and many other clinical symptoms in such diseases as GERD, achalasia, functional belching, systemic connective tissue diseases, HH, etc. Using data on the esophageal motility and LES characteristics for each individual patient, the gastroenterologist, endoscopist, and surgeon have the opportunity to prescribe the drug therapy correctly, and even to formulate the indications and determine the nature and extent of the surgical treatment.

In addition to great opportunities that this method gives us, there are also unsolved questions: the lack of a clear understanding and classification of UES motility disorders, postoperative peristalsis disorders, changes in the motility due to the drug therapy. The diagnostic value of increased or decreased LES resting pressure and minor disorders of peristalsis found in GERD patients is not completely clear. New diagnostic approaches are to be standardized using provocative tests with swallows of fluid and solid food.

The aforesaid demonstrates great prospects for future scientific and clinical research, discoveries and achievements.

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