Open Med. 2018; 13: 232-236 DE GRUYTER

Research Article

Sven Höhne*, Martin Arndt, Viola Hesse

The esophageal manometry with gas-perfused catheters

https://doi.org/10.1515/med-2018-0036
received January 29, 2018; accepted April 21, 2018

Abstract: Background. The well-established methods for esophageal manometry have some disadvantages: the-water-perfused catheters needs calibration by gravity and measuring in supine position, and the solid-state catheters are very expensive. Manometry using gas-perfused catheters is a suitable alternative. There have been only a few publications about this.

Objectives and methods. The results for esophageal manometry in 1700 patients were retrospectively analyzed based on the clinical reports and the manometry data. The gas-perfusion manometry was critically assessed.

Results. The mean age was 54 years. The indications for esophageal manometry were GER symptoms in 58.5% (pathological DeMeester score in 41.8%), dysphagia in 12.4%, and already known achalasia in 8.9%. Motility disorders could be found in 40% of the patients with GER symptoms (51% of the patients with pathological DeMeester score), and in 88% of achalasia patients. The resting LES pressure was 8.9±5.94 mmHg with GER symptoms, 16.4±12.79 mmHg without GER symptoms, and 26.8±14.03 mmHg with achalasia. The relaxation LES pressure was 20.0±10.93 mmHg in achalasia patients, and 8.3±5.77 mmHg in the others.

The gas-perfusion manometry was well tolerated by all patients without any serious complications.

Discussion. Manometry using gas-perfused catheters is an easy to handle and inexpensive method to investigate the esophageal motility. The suitability of gas perfusion with helium for esophageal manometry depends on physical and technical requirements, such as a constant gas flow, a dead space in the transducer, and the catheter being as small as possible. In consideration of this, the detection of the pressure changing in swallowing acts is excellent. The measured LES pressures are generally lower than with other methods like with water-perfused or solid-state catheters, possibly because of the higher compliance in a gas-filled surrounding. The normal values in gas-perfusion manometry are comparable but not identical with the values of other manometric methods.

Keywords: Esophageal manometry; Gas-perfused catheters; Gas-perfusion manometry; Motility disorders; Lower esophageal sphincter; Gastroesophageal reflux

Abbreviations:

GER – gastroesophageal reflux
GERD – gastroesophageal reflux disease
GER-S – gastroesophageal reflux symptoms
LES – lower esophageal sphincter

1 Introduction

The most common esophageal disorders are difficulties in swallowing, e.g. due to achalasia, and the gastroesophageal reflux (GER). The diagnostic gold standard regarding GER is impedance-pH monitoring. In both dysphagia and GER, esophageal manometry is necessary to detect the causal dysfunction of the esophageal motility.

The well-established procedures in this are the manometry with water-perfused catheters and that with solid-state catheters. High-resolution manometry is the most informative methodand therefore the method of first choice for a comprehensive manometric investigation of the esophagus [1]. However, the established manometric procedures have some disadvantages. Water perfusion requires more preparation for the measurement, e.g. the venting of the measuring device and the catheter, and needs to be sterilised because of bacterial contamination.

***Corresponding author: Sven Höhne,** Martin-Luther-University Halle-Wittenberg, University Hospital, Clinic of Pediatric Surgery, 06120 Halle, Ernst-Grube Street 40, Germany, Tel. +49 345 557 3252, Fax +49 345 557 2779, E-mail sven.hoehne@medizin.uni-halle.de
Martin Arndt, Viola Hesse, Martin-Luther-University Halle-Wittenberg, Department of Operative and Conservative Medicine in Children and Adolescents, Clinic of Pediatric Surgery, Laboratory of Function Diagnostic, Germany

The solid-state catheters are very expensive and vulnerable.

Another method for manometric investigation of the esophagus is using gas-perfused catheters. Gas-perfusion manometry with helium was described by Rehak in the 1980s [2, 3]. The advantage of this method is the absence of artefacts due to the mass of the perfusion medium, because helium is practically almost massless. The body position and body movements have no influence on the measuring values. It is not necessary to vent the catheter. The device is clean and need not be dried after measuring compared to water perfusion. With respect to the solid-state technique, cheaper single-use catheters can be applied [4, 5].

The physical properties of gas have certainly some disadvantages. The dead space of the catheter and pressure transducer has to be minimized. The optimal dimensions are no more than 0.4mm in diameter and a helium flow of 5ml per minute in each catheter channel. The length of the channel should be as short as possible.

We have performed esophageal manometry with gas-perfused catheters in the clinic with good experience, in particular in children, for a long time.

2 Material and methods

More than 2700 patients were investigated by gas-perfusion manometry from 1986 to 2014. In order to get a retrospective and representative overview consisting most complete patient data, only 1700 manometric investigations could be included. Additionally, 1028 patients were investigated by 24-hour pH monitoring since 1993.

Esophageal manometry was performed with 5 to 8-channel gas-perfused catheters and extracorporeal pressure transducers. The flow rate of helium was 5ml per minute per each channel.

The perfusion device consists of three components: (1) the gas (helium) cylinder with pressure reducer and the so-called critical flow nozzle, which provides a constant helium flow. The flow depends only on the pre-pressure height. (2) the extracorporal pressure transducer, one for each channel, and (3) the catheter probe.

The investigation included the pressure profile of the esophageal body and LES by the pull-through technique, and the evaluation of the esophageal motility by swallowing.

The results of esophageal manometry and 24-hour pH monitoring were analyzed with regard to the symptoms, indications and diagnoses. The manometric parameters were compared with the values of other manometric methods like water-perfusion and solid-state.

Ethical approval: The study was performed in accordance with the standards of the local ethics committee and the Declaration of Helsinki. No identifying information about the patients is included. All patients have consented to their treatment and investigation, whose data was used in this article.

3 Results

The mean age of the patients was 54 years. 53% were women, 47% were men. The BMI was 26.5 vs. 26.1. The indications for 24-hour pH monitoring were as follows (multiple selection possible): GER-S 79.2% (reflux esophagitis 16.8%, hiatal hernia 27.1%), dysphagia 6.3%, and achalasia 1.2%. The indications for esophageal manometry were: GER-S 58.5% (reflux esophagitis 12.7%, hiatal hernia 22.9%), dysphagia 12.4%, and achalasia 8.9%.

The total length of the esophagus, i.e. esophageal body and both UES and LES, amounted on average 21.9 ± 2.69 cm (n=1521) and was correlated with the body height and weakly correlated with BMI in both male and female.

In 24-hour pH monitoring, the DeMeester score was pathological (> 14.7) in 41.8% (hiatal hernia 61.6%, achalasia 23.1%). In underweight persons, a pathological DeMeester score could be found in 30.4%, in obese persons in 52.3%, regardless of symptoms or indication.

In esophageal manometry, the LES basal pressure was 11.9±10.03 mmHg in all (n=1608), 8.9±5.94 mmHg in the GER-S group (n=957), and 16.4±12.79 mmHg in the group without GER-S (n=651); 8.4±7.08 mmHg in patients with hiatal hernia, 12.9±10.52 mmHg in patients without this. In patients with dysphagia, the LES basal pressure was 14.4±13.41 mmHg (n=206), in patients with achalasia 26.8±14.03 mmHg (n=147).

The relaxation pressure was 20.0±10.93 mmHg in patients with achalasia, 8.3±5.77 mmHg in the others; it means a decrease of 49±33.2% vs. 94±12.7% (n=118 vs. 1328) compared to the LES basal pressure.

Motility disorders could be found in 40% of the GER-S group (n=681), but 61% in the non-GER-S group. Those patients who underwent a 24-hour pH monitoring with a pathological DeMeester score >14.7 (n=603) showed motility disorders in 51%. In the achalasia group (n=84), there were motility disorders in 88%, in the others (n=968) only 44%. In cases of achalasia, ineffective motility with more than 30% of hypotonic contractions (<30 mmHg) was the main part of motility disorders (50%). This percentage in the GER-S group was only 5%.

4 Discussion

The manometry with helium-perfused catheters enables measurements with the same diagnostic accuracy compared to water-perfused systems. Certainly, it is necessary to observe the physical principles, that the constant gas flow needs a pre-pressure height, which is significantly higher than the measuring pressure, and that the quotient of gas flow and dead space shall be as high as possible. What does it mean? The measurable pressure increase per time unit (slew rate) dp/dt is proportional to the flow and inversely proportional to the dead space. The gas flow cannot be arbitrarily boosted but is limited. The investigation in volunteers could show that a flow rate of 40ml per minute over 45 minutes and a total volume up to 1800ml helium is well tolerated without any serious problems. Using an eight-channel catheter, it means the feasible flow rate per channel is 5ml per minute.

Furthermore, the dead space of the transducer unit must be constructed as small as possible. A disposable device is the universal manometry system UMS 5 by the German company Medizintechnik Wadewitz in Leipzig. The diameter of the catheter lumen should not be larger than 0.4 millimeters. If available, 0.2 or 0.3ml would be better. Most of the ready-made catheters for water-perfusion have a size of 0.4ml. We used these catheters with a length about 100cm, the shorter the better. The negative impact of a lower flow and a larger dead space is shown the Figures 1 and 2.

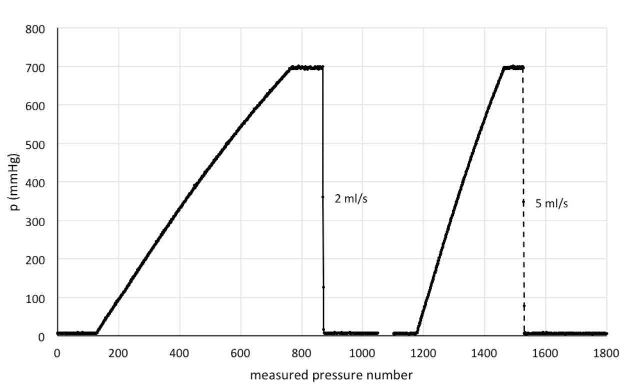

Figure 1: Slew rate dp/dt depended on gas-flow rate of a pressure transducer with about 0.1 mm³ dead space, Flow rate: 2 ml/min (left), 5 ml/min (right), Sampling rate: 50 per second

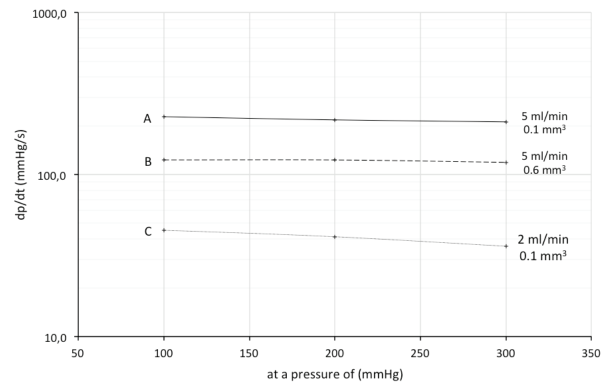

Figure 2: Slew rate dp/dt depended on gas-flow rate and dead space (logarithmically scaled y-axis) A – flow rate 5 ml/min, transducer dead space about 0.1 mm³, B – flow rate 5 ml/min, transducer + catheter channel (diameter 0.2 mm, length 166 cm), dead space 0.6 mm³, C – flow rate 2 ml/min, transducer dead space about 0.1 mm³

Using gas as the perfusion medium provides a number of advantages compared to water perfusion and solid-state technique. Gas has the important feature that it is practically a mass-free medium., therefore the measurement is free of any artefacts by gravitation or mass acceleration. This is why the patients, e.g. children, can move or change the body position during the investigation. It is not necessary to calibrate the measuring system to the body position. The time needed for preparation and proceeding follow-upis short compared to water perfusion because the measuring device and the catheter does not need to be vented and dried before and after the investigation. The advantage over the solid-state technique is the very low cost for the required single-use catheters.

The compulsory precondition for using gas as the perfusion medium is to generate a constant gas flow. The so-called critical nozzle provides the technical solution for this because the flow is not dependent on the measuring pressure, but only on the pre-pressure. The most adverse property of gas perfusion is the compressibility of gas and its spreading in a gas-filled space. This causes no problems when measuring in liquid or more consistent surrounding like a swallowed bolus. However, the side holes will not have direct contact to the esophageal wall at any time in the empty esophagus, e.g. in the LES region. When measuring in a gas-filled compartment, the pressure coupling will get a little worse. Therefore, the measured static pressure, e.g. the basal LES pressure, is generally lower than in water-perfusion or solid-state manometry (Figure 3). The normal value of basal LES pressure is reported as about 25 mmHg, the end-expiratory LES pressure as about 15 mmHg [6-17]. The basal values by gas-perfusion manometry are 13.6±4.17 mmHg in healthy

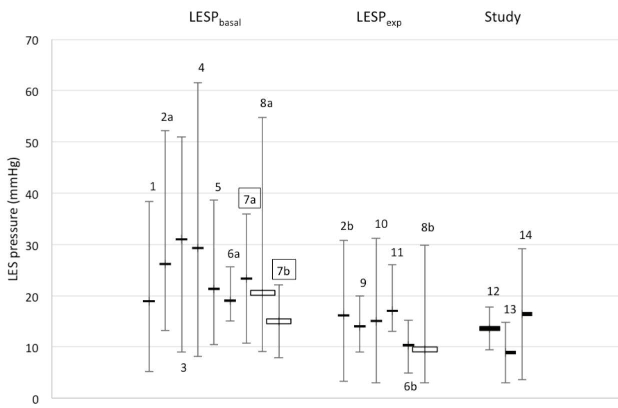

Figure 3: LES resting pressure
$LESP_{basal}$ – basal LES pressure

$LESP_{exp}$ – end-expiratory LES pressure, Study – LES pressure in present study

Markers: black thin bars – solid-state; framed white bars – water-perfusion; black thick bars – gas-perfusion

Statistics: Median and 5th-95th percentile – 1-5, 8, 10; Median and interquartile range – 6, 9, 11; Mean and SD – 7, 12-14

References: 1 [8], 2a,b [9], 3 [10], 4 [12], 5 [13], 6a,b [15], 7a,b [18], 8a,b [11], 9 [16], 10 [14], 11 [17], 12-14 [own]

Selected no.: 7a,b – simultaneously by solid-state (a) and water-perfusion (b); 12-14 in present study – normal values in healthy individuals (12), patients with GER symptoms (13), without GER symptoms (14)

individuals and 16.4±12.79 mmHg in patients without GER symptoms. However, a study by Gehwolf et al. in 2015 has proved that the LES pressure measured in the same individuals is higher when performing solid-state manometry rather than water-perfusion manometry (23.3±12.6 mmHg vs. 15.0±7.1 mmHg) [18] (Figure 3).

Peixoto et al. reported actual results in conventional manometry, but in a smaller patient group of 119 patients. The statement is comparable to our results as follows: mean age 53 vs. 54 years, ineffective motility 45 vs. 47%, diffuse esophageal spasm 5 vs. 5%, and achalasia 25 vs. 25% [19]. Despite the high correspondence, the proportion of hypotensive LES is only 2% at Peixoto, but 26% at our analysis, if the comparison is based on the well-known normal values in water-perfusion and solid-state manometry. In patients with achalasia investigated by HRM, the LES resting pressure was 35-59 mmHg depended on the achalasia subtype, and the integrated relaxation pressure was 25-30 mmHg [20]. We have found 27 and 20 mmHg, respectively. More comparative studies with regard to the various manometric methods are required.

5 Conclusion

Esophageal manometry using gas-perfused catheters is an inexpensive alternative compared to water-perfused and solid-state catheters. The preparation time is short, and the operating costs are low. Although HRM provides more diagnostic possibilities, conventional manometry enables the assessment of the most motility disorders and LES dysfunctions. Therefore, the conventional gas-perfusion manometry is a suitable method for low-budget hospitals treating GERD and performing surgery in hiatal hernia and achalasia. In the clinical practice, gas-perfusion manometry has proven successful for many years, especially in children and moving subjects.

Due to the negligible mass of helium, no artefacts by gravitation or mass acceleration will occur. The measured LES pressure is generally lower than in other manometric methods, particularly in use of solid-state catheters. The detection of rapid changes of the UES pressure is constrained by the limited slew rate.

Further comparative studies are required for a better understanding of the physical conditions concerning the transmission of the real pressure changes from the esophageal wall to the pressure transducers.

Conflicts of interest: The authors declare no conflicts of interest.

References

[1] Bredenoord AJ, Fox M, Kahrilas PJ, Pandolfino JE, Schwizer W, Smout AJ; International High Resolution Manometry Working Group: Chicago classification criteria of esophageal motility disorders defined in high resolution esophageal pressure topography. Neurogastroenterol Motil 2012; 24 Suppl 1: 57-65

[2] Rehak PH: [The manometry in the diagnostics of the esophagus.] Institute of Medical Engineering, University of Technology Graz, Austria 1982, Diss

[3] Rehak PH: [Development of the manometry with gas-perfused catheters] In: Höhne SO, Finke R (Edit): [Diseases of the esophagus in childhood - main focus gastroesophageal reflux.] TENEA Verlag, Berlin 2003, 75-84

[4] Höhne S, Wachter R, Merkel N, Hesse V, Finke R: [Function of oesophagus and gastro-oesophageal reflux in patients with cystic fibrosis]. Z Gastroenterol 2014; 52(4): 343-347

[5] Hoehne S, Schneider A, Hesse V, Brosig U, Finke R: The influence of physical strain on esophageal motility in healthy volunteers studied with gas-perfusion manometry. Neurogastroenterol Motil 2015; 27(8): 1082-1088

[6] Spechler SJ, Castell DO. Classification of oesophageal motility abnormalities. Gut 2001; 49: 145-151

[7] Gyawali CP, Roman S, Bredenoord AJ, Fox M, Keller J, Pandolfino JE, Sifrim D, Tatum R, Yadlapati R, Savarino E;

International GERD Consensus Working Group: Classification of esophageal motor findings in gastro-esophageal reflux disease: Conclusions from an international consensus group. Neurogastroenterol Motil. 2017 doi: 10.1111/nmo.13104. [Epub ahead of print]
[8] Sweis R, Anggiansah A, Wong T, Kaufman E, Obrecht S, Fox M: Normative values and inter-observer agreement for liquid and solid bolus swallows in upright and supine positions as assessed by esophageal high-rsolution manometry. Neurogastroenterol Motil 2011; 23: 509-e198
[9] Niebisch S, Wilshire CL, Peters JH: Systematic analysis of esophageal pressure topography in high-resolution manometry of 68 normal volunteers. Dis Esophagus 2013; 26: 651-660
[10] Bogte A, Bredenoord AJ, Oors J, Siersema PD, Smout AJ: Normal values for esophageal high-resolution manometry. Neurogastroenterol Motil 2013; 25: 762-e579
[11] Kessing BF, Weijenborg PW, Smout AJ, Hillenius S, Bredenoord AJ: Water-perfused esophageal high-resolution manometry: normal values and validation. Am J Physiol Gastrointest Liver Physiol 2014; 306: G491-G495
[12] Do Carmo GC, Jafari J, Sifrim D, de Oliveira RB: Normal esophageal pressure topography metrics for data derived from the Sandhill-Unisensor high-resolution manometry assembly in supine and sitting psitions. Neurogastroenterol Motil 2015; 27: 285-292
[13] Jasper D, Freitas-Queiroz N, Hollenstein M, Misselwitz B, Layer P, Navarro-Rodriguez T, Fox M, Keller J: Prolonged measurement improves the assessment of the barrier function of the esophago-gastric junction by high-resolution manometry. Neurogastroenterol Motil 2017; 29. https://doi.org/10.1111/nmo.12925
[14] Weijenborg PW, Kessing BF, Smout AJ, Bredenoord AJ: Normal values for solid-state esophageal high-resolution manometry in a European population; an overview of all current metrics. Neurogastroenterol Motil 2014; 26: 654-659
[15] Wang D, Patel A, Mello M, Shriver A, Gyawali CP: Esophago-gastric junction contractile integral (EGJ-CI) quantifies changes in EGJ barrier function with surgical intervention. Neurogastroenterol Motil 2016; 28: 639-646
[16] Nicodeme F, Pipa-Muniz M, Khanna K, Kahrilas PJ, Pandolfino JE: Quantifying esophagogastric junction contractility with a novel HRM topographic metric, the EGJ-Contractile Integral: normative values and preliminary evaluation in PPI non-responders. Neurogastroenterol Motil 2014; 26: 353-360
[17] Xie C, Wang J, Li Y, Tan N, Cui Y, Chen M, Xiao Y: Esophago-gastric junction contractility integral reflected the anti-reflux barrier dysfunction in GERD patients. Neurogastroenterol Motil 2017; 23: 27-33
[18] Gehwolf P, Hinder RA, DeVault KR, Edlinger M, Wykypiel HF, Klingler PJ: Significant pressure differences between solid-state and water-perfused system in lower esophageal sphincter measurement. Surg Enddosc 2015; 29(12): 3565-3569
[19] Peixoto A, Morais R, Silva M, Ramalho R, Macedo G: Conventional esophageal manometry in clinical practice: Current impact of its use on patient management. Clin Res Hepatol Gastroenterol 2017; doi: 10.1016/j.clinre.2017.04.014. [Epub ahead of print]
[20] Crespin OM, Tatum RP, Xiao K, Martin AV, Khandelwal S, Pellegrini CA, Oelschlager BK: The relationship between manometric subtype and outcomes of surgical treatment for patients with achalasia: Achalasia: manometric subtypes. Surg Endosc 2017 doi: 10.1007/s00464-017-5570-5. [Epub ahead of print]