Esophageal Manometry

Methods and Clinical Practice

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Urban & Schwarzenberg

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57 Figures and 15 Tables

Urban & Schwarzenberg
Baltimore – Munich 1981

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Germany

Library of Congress Cataloging in Publikation Data

Weihrauch, Thomas Robert.
Esophageal manometry.
Includes index.
1. Esophagus-Diseases-Diagnosis.
2. Manometry.
3. Esophageal motilyti. I. Title.
RC815.7.W44 616.3'20754 81-11430
ISBN 0-8067-2151-0 AACR2

Printed in Germany by L. Auer, Donauwörth

ISBN 0-8067-2151-0 Baltimore

ISBN 3-541-72151-0 Munich

Preface

During the past decade, manometry has become an important diagnostic tool in the evaluation of gastrointestinal motor disorders and in the quantitative assessment of the effect of medical and surgical therapy. Methods for pressure recording have finally achieved sufficient accuracy though an ideal measuring device has not yet been developed. Almost a century of pressure recording has elapsed since Kronecker and Meltzer's first studies in 1883, and it now seems necessary to summarize modern manometric methods for the growing number of investigators interested in either clinical diagnostic manometry or research or both. Since the first atlas on esophageal motility in healthy and diseased states by Charles F. Code and coworkers, appeared in 1958, much progress has been made and a large body of knowledge has accumulated concerning methods, physiology, and pathophysiology of gastrointestinal motility.

First the historical background of the development of manometric methodology is reviewed then the important factors of clinical manometry are presented for both the beginning as well as for the more experienced manometrist. The young manometrist may be puzzled, confused, and discouraged when he compares his first, ill-defined tracings to the classical textbook figures that have been obtained through experience and educated selection. With increasing experience, he will discover the similarity of his tracing to those depicted in this book.

If this summary of the knowledge of esophageal manometry, technology, and clinical applications will benefit the further development of clinical manometry and thus the patient, the purpose of this book will have been fulfilled.

Acknowledgements

I would like to thank my coworkers H. Alpers, M. D., H. Biewener, M. D., A. Brummer, M. D., and P. Vallerius, M. D. for their assistance in a great number of the studies that were the impetus for this book; Professor F. Waldeck for his valuable suggestions; Mrs. I. Ehrlich, Mrs. H. Winkler and Mrs. I. Todt for typing the manuscript; Mrs. B. Busch for her photographic work, and Urban & Schwarzenberg for the realization of this project.

Abbreviations

UES	Upper esophageal sphincter
UESP	Upper esophageal sphincter pressure
LES	Lower esophageal sphincter
LESP	Lower esophageal sphincter pressure
HPZ	High pressure zone
SPT	Station pull-through
RPT	Rapid pull-through
AC	Abdominal compression
PSS	Progressive systemic sclerosis
PIP	Pressure inversion point
SD	Standard deviation
SEM	Standard error of the mean

Weihrauch

Esophageal Manometry

Contents

Chapter 1. Introduction

Manometric studies of gastrointestinal motility were performed almost a century ago by Kronecker and Meltzer, who published the results of their investigation of esophageal motility in 1883. Since then gastrointestinal manometry has become an established diagnostic procedure, especially because of the developments of the past tree decades. Using this method, motor abnormalities of the body of the esophagus and its sphincters as observed in gastroesophageal reflux disorder, achalasia, progressive systemic sclerosis, diffuse esophageal spasm, and diabetic polyneuropathy may be quantitatively assessed. In the differential diagnosis of Barretts' disease, of angina-like chest pain, or of megaesophagus, manometry may prove to be the only method for establishing the diagnosis. Only recently, through manometric studies, the association between gastroesophageal reflux and chronic bronchitis, recurrent pneumonia and mimicked neurological and psychiatric syndromes, respectively, have been recognized in infants (Danus et al., 1976, Moroz et al., 1976, Bray et al., 1977, Euler and Ament 1977 a and b, Whitington et al., 1977).

Increasingly, esophageal manometry has been used to prove the efficacy of operative procedures. Through pre- and postoperative pressure measurements the efficacy of procedures for the reconstruction of a gastroesophageal reflux barrier have been assessed. The effect of cardiomyotomy or pneumatic dilatation on lower esophageal sphincter (LES) pressure can also be quantified. Furthermore, the indication may be confirmed by preoperative manometry in addition to radiological and endoscopic examinations. Finally, manometry offers the possibility of establishing the effect of gastrointestinal hormones or drugs on gastrointestinal motility in health and disease.

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Chapter 2. Historical Development of Methods for Intraluminal Esophageal Manometry

Balloon Kymography

The first manometric motility studies of the gastrointestinal tract were performed by Kronecker and Meltzer in 1883 and by Meltzer in 1894 using balloon kymography (see Table 1). In these studies, air-filled balloons were used as pressure transmitters. Water-filled balloons have been used in physiological and clinical studies since 1940 by Ingelfinger and Abbot, Brody et al. (1940), Hightower et al. (1949), and Rowlands (1962). Because of inaccurate and delayed assessment of rapid pressure changes, dependence of sphincter pressure measurements on balloon diameter, and the effect of the balloon on motility, balloon kymography was abandoned (Brody and Quigley, 1951, Pope, 1967, Rinaldo and Levey, 1968, Shepherd and Diamant, 1972, Wienbeck, 1976). With the use of small liquid-filled balloons, however, measuring methods could be improved, so that in lower esophageal sphincter (LES) pressure recording this method was superior to use of non-perfused catheters as pressure transmitters (Code and Schlegel, 1958). Waldeck et al. (1973) successfully recorded pressure changes in the upper esophageal sphincter (UES) during swallowing using a low-elastic polyester balloon. For routine use, however, the balloon method was found not valuable.

Water Perfused Catheters

The introduction of water perfused catheters with end or side openings as pressure transmitters to extracorporeal transducers (e. g., Statham-transducers) represented a new step in gastrointestinal manometry. The first studies using this method were performed during the 50s by Quigley et al. (1950), Quigley and Brody (1952), Sanchez et al. (1953), Ingelfinger et al. (1954), Lorber and Shay (1954), Sleisinger et al. (1955), Fyke et al. (1956), Creamer et al. (1956), Muller-Botha et al. (1957), Texter et al. (1957), Code and Schlegel (1958), Code et al. (1958), Hightower (1958), Pert et al. (1959). Although basic knowledge of the physiology and pathophysiology of esophageal motility was revealed, the studies of Harris and Pope (1964), Pope (1967), Winans and Harris (1967), and Cohen and Harris (1970) showed that only by the use of constantly perfused catheters could quantitative results be obtained. This improved method, showed for the first time a relevant correlation between the resting pressure of the LES and the symptoms of gastroesophageal reflux (Pope, 1967, Winans and Harris, 1967), as well as that between the resting pressure of the sphincter and its force of closure (Cohen and Harris, 1970).

Another important improvement in sphincter methodology was the observation that only by the continuous pullthrough of the catheter through the LES with defined velocity and perfusion rate can the sphincter pressure be accurately measured (Waldeck, 1972). It was shown that with step-wise pullthrough of the catheter through the LES or stationary catheter placement in the LES, which was the current practice, false-low pressures were measured. With the rapid pullthrough technique developed by Waldeck using a single lumen catheter with four side holes, LES resting pressure could be recorded quantitatively for the first time. These results were confirmed by Dodds et al. (1975). The application of this rapid pullthrough technique (RPT) made esophageal manometry, at least LES-manometry, a truly quantitative method, which gave exact and reproducible results.

Recently other methods have been described for LES manometry. Among these are pressure constant perfusion manometry (Kunath, 1975) and the "sleeve" method (Dent, 1976), where the pressure recording part of the perfusion catheter is stationary in the LES for continuous pressure recording. The suitability of these methods for wide clinical application cannot be sufficiently assessed at present.

With the rapid pullthrough technique the problem of LES pressure recording was satisfactorily solved by a somewhat cumbersome but accurate measuring device. However, rapid pressure changes and high pressures observed during swallowing in the body of the esophagus or in the upper esophageal sphincter (UES) could only be approximately measured by highly perfused catheters (Stef et al., 1974, Zabinski et al., 1975). The methodological possibility of increasing the perfusion rate was limited because the perfusion fluid itself influenced esophageal motility (Dodds et al., 1973, Zabinski et al., 1975, Arndorfer et al., 1977).

An important improvement in perfusion manometry was achieved by the development of the hydraulic-capillary infusion system (Dodds et al., 1974, Arndorfer et al., 1977), by which quantitative measurements are achieved using a low perfusion rate (0,6 ml/min). Therefore, this system seems to be suitable not only for LES pressure recording but also for a measurement of peristaltic pressure waves. However, this system is not suitable for the recording of UES pressures since its recording accuracy is limited to 200 mm/Hg.

The clinical disadvantages of perfusion manometry are the timeconsuming filling of the system, the necessity of a motorized device for exact sphincter pressure recording, hydraulic artefacts, problematic disinfection of the catheter assembly, and a catheter compliance which cannot be completely eliminated.

Intracorporeal Microtransducers

The development of suitable intracorporeal microtransducers that convert pressures directly into electrical signals had early success, but these sensors did not meet the expectations raised by this technical advance. Quigley et al. (1950) and Butin et al. (1953) described esophageal pressure recordings with an electromagnetic transducer. This transducer originally designed in 1950 by Gauer and Gienapp for intraarterial and intracardial pressure recording, was based on an inductive principle developed by Wetterer (1943). Butin et al. reported their results in 1953 at the meeting of the American Gastroenterological Association. This initial application of an intracorporeal transducer in gastrointestinal manometry was enthusiastically received by Ingelfinger: ‘I have to admit that this presentation gives us one of the first fruits of an idea which gastroenterological physiologists have had for some time; namely, that of measuring enteric motility, not by balloons, which produce their own stimulated motility, but by direct recording of the pressures that occur spontaneously and may be responsible for symptoms’.

The hope that a direct, intracorporeal method for esophageal manometry had been found that would replace indirect methods such as balloon manometry or water-filled catheters as pressure transmitters, was not realized. Although Fyke and Code (1955), Code et al. (1958), and Hightower (1958) initially used this transducer, problems with the pressure transmission became apparent in the long run which were mainly due to the tip position of the transducer membrane. In contrast to pressure recordings in fluid-filled systems with circumferentially equal pressure transmission (as in intravascular or intracardial pressure recording), the transducer membrane should be at the side of the catheter for gastro-intestinal pressure measurements. Therefore, this method was abandoned in favor of the indirect recording method using fluid-filled catheters as pressure transmitters.

In 1968 a new intracorporeal transducer was described by Millhon et al. Instead of the electromagnetic principle of Wetterer (1943), the principle of changing resistance using a strain gauge was applied. New intracorporeal transducers developed during the following years as commercially available systems by Sensotec (Esophageal Motility Probe, Model EMP-3), by

Table 1. The development of manometric methods for esophageal function studies. (I. D.) inner diameter, (ED) external diameter, (SO) side openings, (L) length, (PR) perfusion rate, (LES) lower esophageal sphincter. The dimensions are given in mm if indicated in the publications.

Authors	Year	Methods	Remarks
I. Methods with extracorporeal transducer			
Kronecker and Meltzer	1883	Balloon-kymography (air-filled balloons)	
Quigley et al.	1950	Helium-perfused open tip catheter	
Muller-Botha	1957	Unperfused waterfilled tip catheter	Continuous manual pull-through
Code et al.	1958	Three unperfused waterfilled catheters with side openings, ID 0.75	
Winans and Harris	1967	Constantly perfused catheter with side openings, ID 1.4, SO 1.2, PR 0.3–0.5 ml/min	For the first time differentiation between competent and incompetent LES possible by constant perfusion
Pope	1967 1970	Constantly perfused catheters with side openings, ID 1.6, SO 1.0, PR 2.4 ml/min station pullthrough	Proved the necessity of higher perfusion rates for quantitative pressure recording
Waldeck	1972	Rapid pullthrough technique, single lumen 4-hole-catheter, ID 3.6, SO 1.0, PR 5 ml/min, pullthrough velocity 6 mm/sec	First truly quantitative LES pressure recording
Waldeck, Jennewein and Siewert	1973	Balloon catheter consisting of little extensible polyester material, ED 5.0, ID 30.0	
Dodds, Arndorfer et al.	1974	see Arndorfer et al., 1977	
Dodds et al.	1975	5-lumen constantly perfused catheter, ID 1.6, PR 1.6 ml/min, pullthrough velocity 0.5 to 1.0 cm/sec	Confirmed the superiority of the rapid pullthrough technique in LES pressure recording
Kunath	1975	Perfusion manometry at constant pressure, pressure capsule ED 4, L 8	Measurement of LES compliance (yield pressure)
Dent	1976	Perfusion catheter with 5 cm "sleeve", ED 5.5, PR 1.3 ml/min	3-lumen catheter with "sleeve" for continuous LES pressure recording
Arndorfer, Dodds et al.	1977	Hydraulic capillary infusion system without pumps and syringes, 4 (6)-lumen catheter, ID 0.8 and 1.1, PR 0.6 ml/min	First quantitative measurement of peristaltic pressure waves with a perfused catheter system

Authors	Year	Methods	Remarks
II. Methods with intracorporeal transducers (microtransducer)			
Gauer and Gienapp	1950	Electromagnetic transducer ED 3.1, L 20	Developed for intraarterial and intracardial pressure recording
Butin et al.	1953	First application of the Gauer and Gienapp transducer for esophageal manometry	
Millhon, Crites et al.	1968	Semiconductor-type transducer, ED 7.9	Side positioned pressure membrane
Honeywell Model 31 probe (Hollis and Castell)	1972	Semiconductor type transducer, based upon the Millhon-Crites probe	Side positioned pressure membrane, 3 equally oriented transducers
Kaye et al.	1973	Semiconductor type transducer, ED 6.0	Circumferential pressure recording by surrounding the transducer with a water-filled chamber
Waldeck, Jennewein and Siewert	1973	Semiconducter type transducer	Circumferential pressure recording by surrounding the transducer with a water-filled polyester balloon
Förster, Weihrauch et al.	1976	Electromagnetic transducer with 2 lateral crescent shaped pressure cams, ED 6.0, L 9.0	Almost circumferential pressure sensitivity (240°), temperature stability, mechanical durability

Millar Instruments (Mikro-tip Pressure Transducer), and Honeywell (Esophageal Probe model 31) were based on this principle. Although these highly sensitive measuring systems enabled quantitative assessment of sphincter pressures and peristalsis (Hollis and Castell, 1972, Stef et al., 1974, Dodds et al., 1976), the problem of temperature sensitivity, which reduces measuring accuracy, has not been satisfactorily resolved. Because of their low mechanical resistance these systems are not suitable for routine use (Dodds et al., 1976). Another disadvantage of these probes is that they are equipped with only a small pressure sensitive membrane at the side of the catheter, which records the wall pressure from only a small segment. Therefore, both Waldeck et al. (1973) and Kaye et al. (1973, 1977) developed a new catheter which consisted of a semiconductor transducer surrounded by a fluid-filled polyester balloon and a fluid-filled chamber, respectively. A circumferential sensitivity of the transducer was thereby achieved. However, the problems of temperature sensitivity and low mechanical resistance persisted with these catheters. Another problem was the manufacturing of these devices. Therefore, these catheters have not found wide acceptance.

The challenge to develop a suitable measuring method for gastrointestinal manometry was pursued again from 1971 on by Förster and the Institut Dr. Förster, Reutlingen, West Germany. An intracorporeal electromagnetic pressure transducer was developed, and was ready for clinical use in 1975 (Förster et al. 1976, Förster et al. 1977, Weihrauch and Förster, 1977). This system is highly linear, noncompliant, and not temperature sensitive. It is almost circumferentially sensitive, has a high mechanical resistance, is easy to handle, and may be disinfected conveniently. However, since the measuring probe is still equipped with only one transducer at the time of this writing, the progression of peristaltic waves cannot be recorded (Table 1, page 000, Table 2, page 000).

It may be concluded that there is no ideal recording system for esophageal manometry at present. Therefore, a great variety of methods is used. Results of different investigators are therefore not directly comparable, and normal values must always be defined for any given method. It is hoped that this situation, which is comparable to the confusion of languages during the building of the Tower of Babel, will soon be brought to an end by the development of a generally accepted measuring device.

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