Longterm high resolution manometry (HRM) challenges and pitfalls of an automated motility analysis

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Introduction

High resolution manometry (HRM) of the esophagus is the gold standard in the diagnosis of esophageal motility disorders[1]. However, it only measures a short period of time and allows only to distinguish between the most common esophageal motor abnormalities with the help of Chicago Classification[2]. As the measurements take place in clinic for a very limited period of time only little is known about circadian changes in esophageal motility. Especially for patients with intermittend symptoms conventional, short-term HRM cannot assess the underlying causes of the disease precisely.

Therefore, we prolonged the time of measurement to a full of 24 hours using a combined ambulatory impedance-manometry device consisting of 36 pressure channels and 15 impedance channels[3]. With this setting it is possible to examine esophageal motor function throughout a whole day whilst the patient is following her/his normal duties.

The aim of our project was to etablish normal values for healthy persons and to identify patients with transient esophageal problems as only little is known about normal and pathological patterns when examining esophageal motor function and dysfunction throughout a whole day.

Materials and Methods

For the longterm high resolution manometry (HRM) we used a 10 French Solide State Manometry catheter designed for high resolution impedancomanometry studies (Unisensor, Attikon, Swiss). In the probe, the esophageal pressure values are already digitalized and sent to the portable recording unit MALT™ (Standard Instruments, Karlsruhe, Germany). With the power supply of two standard lithium AA-batteries the systems allows studies up to 26 hours. The recording unit has an internal memory of 1 GB size and can store pressure plots of 36 pressure channels with a rate of 50 Hertz without the necessity of data compression.

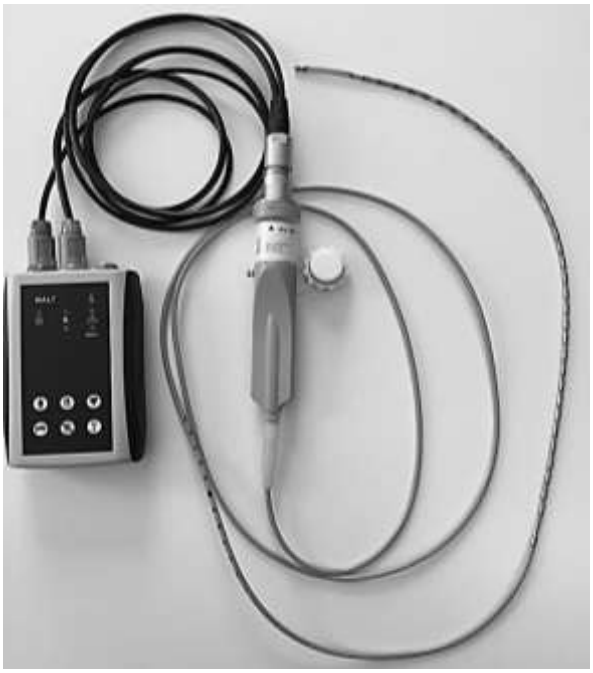

Figure 1: Device for ambulatory high resolution manometry of the esophagus

In addition to the huge amount of pressure raw data, complementary information on body position, eating and drinking habits as well as sleeping is integrated into the dataset.

With this newly developed device we have been recording more than 80 longterm high resolution manometries since the beginning of our project. Technical and clinical feasibility was documented prospectively and iteratively improved.

Evaluation

The 24 hour recordings of normal, healthy test persons were manually analysed. An extended Chicago classification system was used (Fig. 2).

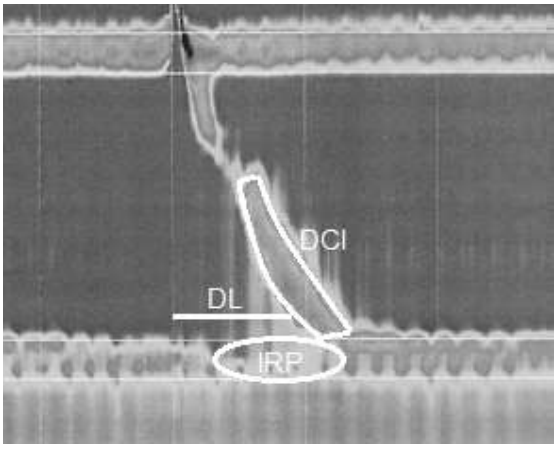

Figure 2: Important values for evaluation of esophageal motility according to Chicago Classification Version 3.0 (DL = distal latency, DCI = distal contraction integral, IRP = integrated relaxation pressure)

Parallely, an automated analysis program was developed, based upon the classical Chicago criteria. An act of swallow was assumed as soon as a relaxation of the upper esophageal sphincter (UES) was followed by sequential contractions measured by the more distal sensors. With the ongoing evaluations, it became clear that this rather rigid algorithm had to be changed as described below.

Results

Technical and organizational problems

Though the probe is quite rigid and has a diameter of about 3mm (10 French) the examination is accepted by our patients and in our healthy volunteers quite effortlessly. Only three measurements had to be stopped before time.

More problematical in the performance of longterm high resolution manometries are technical aspects. The used solid state probes are high end products and are designed for about 200 uses (about 600 operating hours). When extending the time of measurement to 24 hours, the guaranteed operating hours are reached within 25 measurements which rises the costs of a single measurement to around 720 €. Especially with the longterm use the probes need more repairement and checking which adds additional costs to each examination.

Manual Evaluation

Up to now there is no program for automated computer analysis of HRM and especially non for long-term measurements available.

As expected, manual analysis of the pressure recordings was extremly tedious and time consuming. However, it yielded important new insights.

"Static" parameters

These so called static parameters represent the resting pressure of both high pressure zones in the esophagus: the upper and the lower esophageal sphincters.

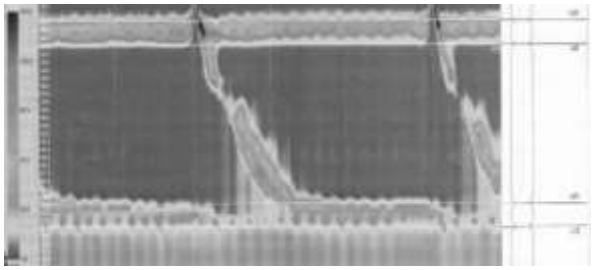

Figure 3: Color-coded HRM pressure plot of a normal swallow that starts with relaxation of upper esopheal spincter, followed by a propulsive peristalsis and ends by contraction of the lower esophageal sphincter. (right: marking of pressure bands of upper and lower esophageal spincter)

We found that physiological (complete) swallows as shown in the figure above (Fig. 3) do not at all represent the majority of all motor events of circadian esophageal motility. Depending upon posture (upright/prone) and food intake, a considerable number of incomplete swallows occurred. In these instances, a clear relaxation of the UES is not observed, but the distal conctractile sequences show the typical pattern.

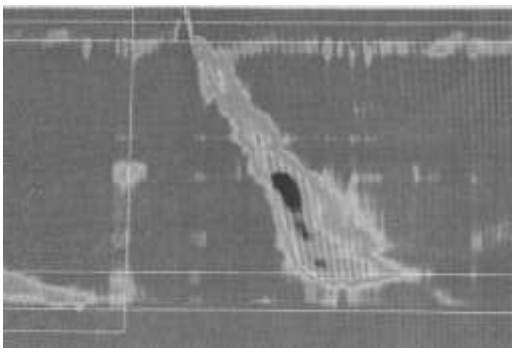

Figure 4: Relaxation of the UES is barely visible. Though a human analysist would recognize the act of swallowing, a machine based system would certainly not recognize this type of motor event

Even more surprisingly, irregular motor events could be detected in healthy people without any esophageal problems. Retropulsive contractile sequences could be observed as well as distal cramps (Fig. 4) or transient relaxations of the lower esophageal sphincter (TLESR) which were often followed by reflux (Fig. 5).

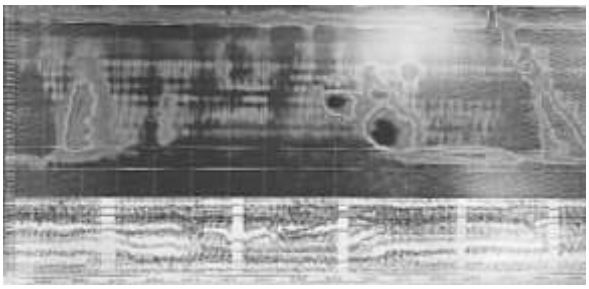

Figure 5: Transient sphincter relaxation, followed by fluid reflux (as seen in impedance measurement at below the HRM plot) and a distal contractile wave before an act of clearance swallowing

Systematic further classification of the normal motility pattern is currently conducted. Up to now, we are still unable to present a complete catalogue of physiological circadian pressure events. At any rate, "irregular" contractile events which were considered pathological in our previous analyses can be found frequently in normal test persons as well.

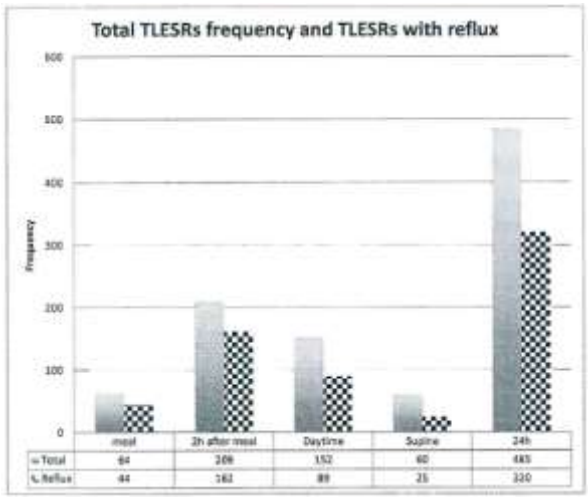

Figure 6: Total number of TLESR and TLESR with reflux

When analysing our patients with reflux disease it shows that the mean resting pressure of the lower esophageal sphincter underlies a slight modulation with an increase of resting pressure and the integrated relaxation pressure during nighttime. Whereas in the upper esophageal sphincter resting and relaxation pressure stay stable throughout the measurement. Most remarkably, the number of TLESR are appearingly dependent of the circadian cycle.

Dynamic parameters

Dynamic parameters is the preamble for all values that can only be measured during an act of swallowing (eg. transportation velocity, area under the curve).

In patients with known reflux disease significant changes in the cause of measurement can be seen in the value of DCI (distal) and PCI (proximal contraction integral), the intrabolus pressure (IBP), in distale latency (DL) and distal contraction velocity (DCV).

Problems of automated analysis

As manual analysis is not feasible in clinical practice it is by now possible to get a computer aided analysis according to the newest Chicago Classification. These computer aided programs tend to correctly mark pressure landmarks during swallowing whenever an act of swallowing is marked correctly beforehands. For an expert in analysis of HRM the analysis of a whole dataset can be performed in around 20 hours which excludes it from clinical routine.

Originally an algorithm for detecting an act of swallowing was developed which relied on the pressure changes in the UES. A swallow was assumed if a relaxation in the upper esophageal sphincter was followed by a characteristic postdeglutitive increase of pressure.

The rate of complete swallows that can be evaluated with measurements of the parameters shown in Fig. 1 was very high (>95%) but unfortunately these typical contractile sequences made up only about 1/3 of circadian motor events of the esophagus. Especially motility patterns without oropharyngeal triggering of a swallow (e.g. secondary peristalsis waves for esophageal clearance, …) aren't considered for analysis at all [4]. Whilst typical motor events can be evaluated with computer-assisted programs the remnant has still to be evaluated manually.

Conclusion

Analysis of longterm high resolution manometry (HRM) is at the moment not yet feasible in clinical routine. It is essential to develop a computer program to bring longterm HRM into clinical practice. As shown above, automatic analysis is by far more complex than it is when performing short time analysis according to the Chicago Classification. As there are

up to now no bigger series on normal and pathological values with longterm manometry studies it is hard to define new, more suitable algorithms for computer analysis of HRM. Further studies will be necessary to build up a big database of normal and pathological values as well as newer and more elaborated algorithms (eg. deep learning methods) will be necessary for a better understanding of circadian motility patterns of the esophagus.

Conflicts of interest:

No conflict of interests. The project was supported by Dr. Pfleger-Stiftung Bamberg, Germany.

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