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METHODS OF STUDYING GASTRO-INTESTINAL MOTILITY: LARGE INTESTINE

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SUMMARY

The colon serves to absorb fluid and electrolytes, to mix its contents, to store its contents and to empty it in a controlled fashion. Motility, absorption and secretion closely interact to fulfil these functions. Tone, phasic contractions and ano-rectal closure are the main principles of colonic motility. They are controlled by the enteric nervous system. Colonic motility differs from that in other parts of the gut in that it is very slow and irregular, coordinated activity is rare and orad movements normal.

The methods to study colonic motility are radiology which is largely abandoned, manometry with perfused catheters or ambulant with tip catheters, the use of the barostat, radioscintigraphy, marker transit, and electromyography. They all measure different aspects be it flow of colonic contents as in radioscintigraphy and marker transit or be it wall contractions as in manometry and electromyography or be it tone as in the barostat. They are therefore complimentary.

So far, only marker transit in the colon and manometry in the ano-rectum are widely clinically used.

INTRODUCTION

The colon serves to absorb fluid and electrolytes, to mix its contents in order to facilitate absorption, to store its contents and to empty it in a controlled fashion (*Wienbeck* et al., 1990). This is controlled by a very complex interplay of myogenic and neural structures, by the action of peptides and other neurotransmitters, by local mediators and by intraluminal contents be it food remnants or be it bacteria, fluid, toxins and other ingredients of faeces. The enteric nervous system of the colon closely interacts with the smooth muscle of the organ which is responsible for the wall movements. The enteric nervous system receives inputs from local afferent nerves, from the central nervous system and from interneurons. It serves to integrate and program all inputs and to transform them into outgoing signals.

Colonic motility is only one function of the organ (*Karaus* and *Wienbeck*, 1988). It closely interacts with absorption, secretion and immuno-regulatory functions of the large intestine. The mechanisms of motor action are tone, phasic contractions and the anorectal closure which prevents uncontrolled outflow of colonic contents. The phasic contractions of the colon may either be stationary and segmenting serving

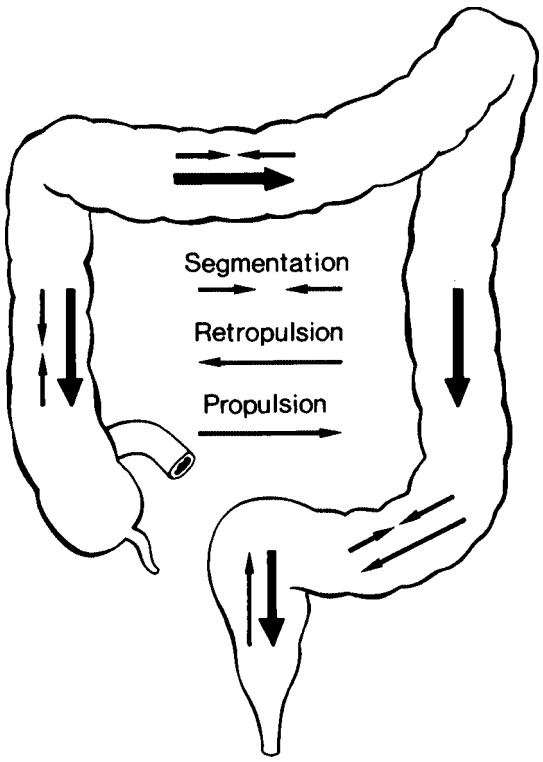

Figure 1: Schematic illustration of phasic colonic motility.

mainly to mix the contents or propagated serving to propel contents (Figure 1). In the descending colon and rectum propulsive contractions prevail whereas in the other parts segmenting contractions are predominant.

Colonic motility differs from that in other parts of the gastro-intestinal tract in several aspects:

1. Propulsion in the colon is very slow. Emptying occurs within days. Ultra-slow variations in activity may be seen, e.g. circadian rhythms (Figure 2; *Wienbeck* and *Kreuzpaintner*, 1976).
2. In addition, colonic motility appears to be rather irregular. Therefore the normal range is very wide. This has to be taken into account when abnormalities are looked for.
3. Coordinated activity, e.g. mass movements, is recognized only intermittently.
4. Retrograde (orad) movements are normal in the colon and occur quite frequently.

METHODS

A series of different methods have been introduced over decades in order to study colonic motility. Since colonic motility comprises different aspects of movements of the large intestine, the methods developed to study it pay attention either to the movements of contents within the large intestine and their characteristics which are called patterns of flow or they measure the movements

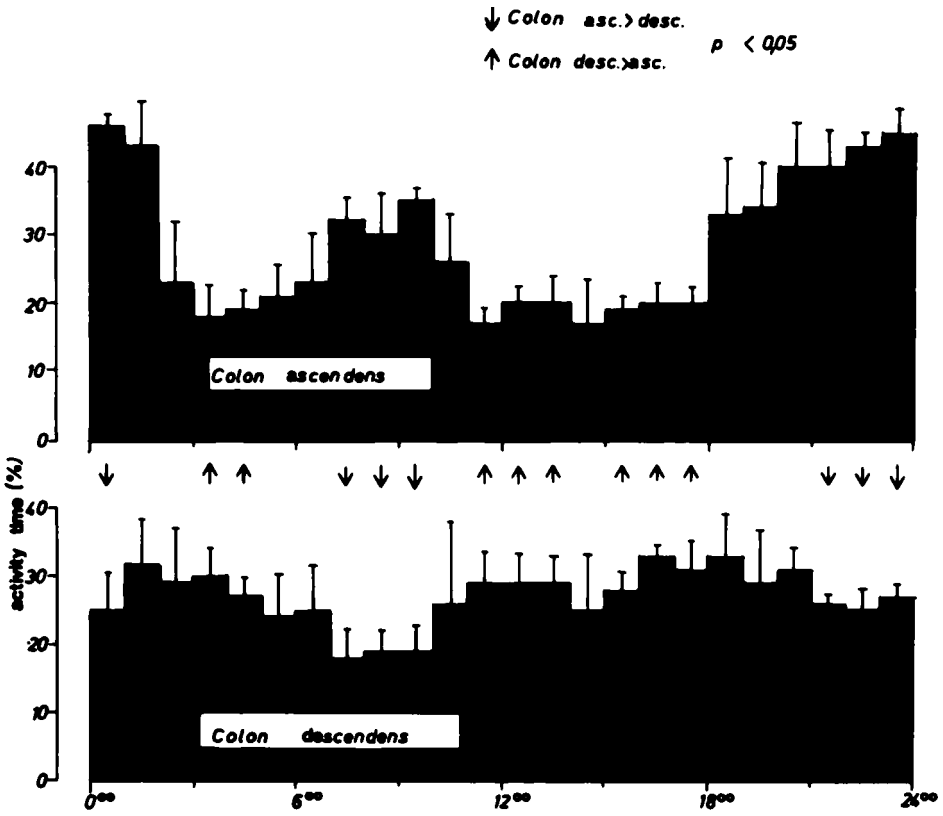

Figure 2: Circadian rhythm of colonic motility as recorded by electromyography in the cat.

of the colonic wall called motor patterns (*Karaus* and *Wienbeck*, 1991). When two methods are combined and flow and motor activity are measured at the same time, the two aspects can be correlated with each other in order to better understand colonic physiology and pathophysiology.

The well established methods for studying colonic motility are:

1. Radiological methods using contrast material previously brought into the colon.
2. Manometric methods in order to measure pressure changes within the colon and to conclude from these on wall movements of the large intestine.
3. The barostat which in its original form serves to measure volume changes of a balloon brought into the colon.
4. Radioscintigraphy after instillation of a radioactive marker into the proximal colon in order to continuously investigate movements of colonic contents.
5. Marker transit after previous ingestion of a number of radio-opaque markers and follow-up either by abdomen X-rays or X-ray films of the collected faeces.
6. Electromyography which measures the muscle activity by collecting its fast and slow signals.

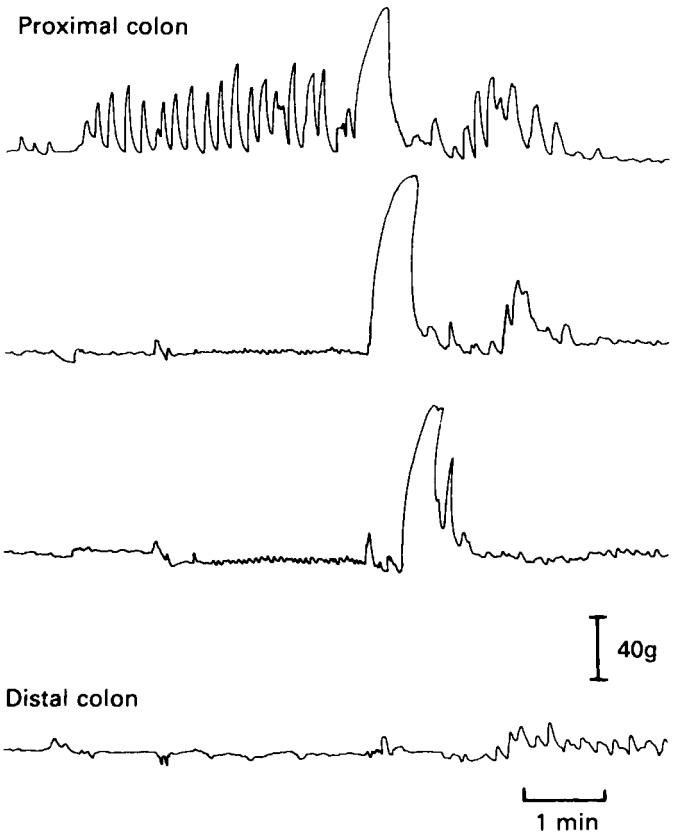

Figure 3: Giant migrating contraction in the colon ("Massenbewegung").

RESULTS (PRACTICAL USE)

The methods used to study colonic motility have received different attention and practical applicability which will be described here.

1. Radiology

Radiological methods were the first to study the movements of colonic contents. Already Holzknecht described with this method in 1909 mass movements which propelled major parts of colonic contents from the right to the left colon or even further to defecation (Figure 3). But the method is no longer used to study colonic motility because of its inherent problems which will be discussed later.

2. Manometry

Manometric methods date back about one century. At that time balloons were used to pick up pressure changes and thus record motility. The balloon catheters are largely replaced by either open-ended perfused catheters nowadays or by solid-state tip catheters. In contrast to the balloon catheters these newer catheters measure the intraluminal pressures only and not pressures exerted upon distending balloons (Figure 4). Intraluminal pressure changes largely reflect phasic wall movements whereas changes in tone rarely show up with these methods.

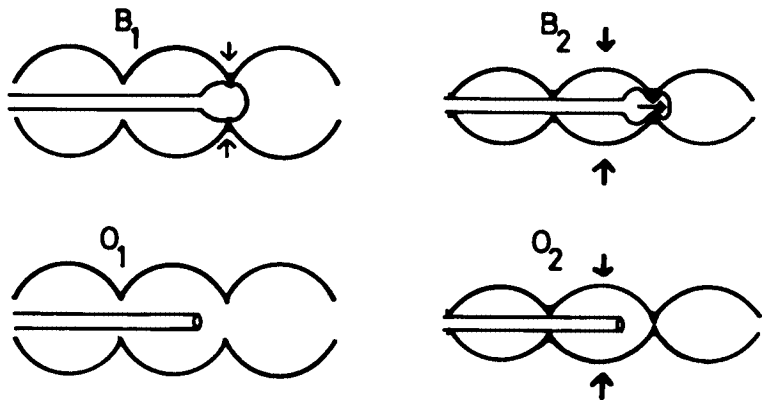

Figure 4: Recording colonic motility by balloon and perfused open-ended catheters. In this example balloon catheters show each wall contraction whereas open-ended catheters show a pressure rise only if a pressure chamber develops (O_2).

a. Stationary manometry

Stationary manometry with perfused open-ended catheters and stepwise pull back is the standard method in ano-rectal manometry which serves to analyse patients with defecation problems. The method is also used as a research tool in all parts of the colon introduction becoming more difficult the more orad the catheter is placed.

b. Ambulant manometry

Since colonic motility changes very slowly over time and motility patterns of long duration have to be taken into consideration, long-term manometry in an ambulant environment is a more physiologic way of studying colonic motility than stationary motility measured in a recumbent position. With the advent of solid-state recorders with large storage capacity ambulant manometry with tip catheters has become reality. It demonstrates that the overall motility of the proximal, but not of the distal colon increases as the large intestine fills up from the first to the second day of the study (M. Karaus, personal communication) and that in contrast to previous thinking the measured motor activity is higher in diarrhoea than in non-diarrhoeal states at least in the irritable bowel syndrome.

3. Barostat

Since the barostat measures volume changes of an inflated balloon of defined size and location, it is the method of choice to study tone in the different parts of the gastro-intestinal tract. So far, it has been used in the recto-sigmoid. The balloon if gradually inflated can also be used to test for rectal compliance, sensation and pain thresholds. So far, it is mainly a research tool, but this may change rapidly.

4. Radioscintigraphy

In contrast to the upper digestive tract where radioscintigraphy has been extensively used to measure the location of physiologic contents and their flow, the colon was neglected for a long time. Orally taken isotope markers because of their decay and overlap were not useful to study transit in the large intestine. This situation changed when radio-isotopic markers were applied locally just above the area of interest through tubes swallowed by the subjects before. The practical usefulness of this method for studies in the clinical routine has still to be demonstrated.

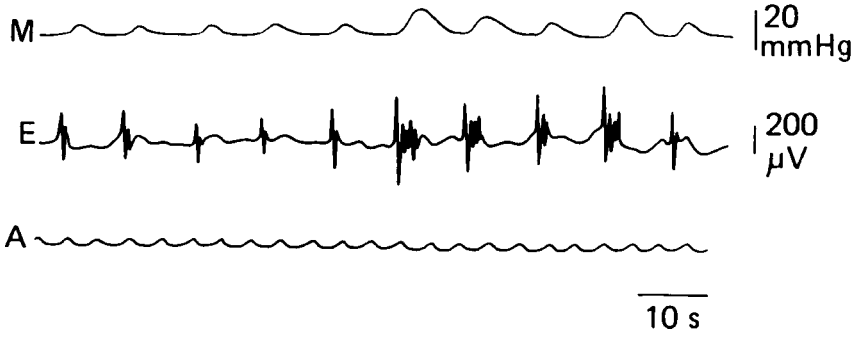

Figure 5: Electrical (E) and manometric (M) recording in the human recto-sigmoid. (A) denotes respiration. Short spike bursts superimposed on electrical slow waves are accompanied by single, low amplitude contractions.

5. Marker transit

The use of colour markers, e.g. charcoal, is an old method of studying oro-caecal transit time. But more reliable radio-opaque markers have largely replaced the colour markers as a diagnostic tool. The so-called Hinton method gave only 1 test dose of 20 markers whose appearance was tested in the stools by X-ray. Fractionated marker application over several days and an X-ray picture of the whole abdomen yields more information in that it allows for easy calculation of the differential transit times from mouth to the right, left and distal colon. Marker transit studies are the most widely used methods of studying colonic transit.

6. Electromyography

The signals which are picked up by electromyography from the colon may be differentiated into spikes, slow waves and oscillations (*Karaus* and *Wienbeck*, 1989). Spike bursts and oscillations are accompanied by muscle contractions as their mechanical counterpart whereas slow waves (synonyms: electrical control activity, pacesetter potentials) largely serve to time the occurrence of spikes and spike bursts (Figures 5 and 6). The method has been widely used in experimental animals, but apparently has lost interest in clinical studies.

DISCUSSION

All methods of recording colonic motility encounter a number of problems which restrict their use. They either measure movements of contents, i.e. radiology, radioscintigraphy and marker transit, or muscle activity, i.e. manometry, barostat and electromyography. In most studies the colon has to be prepared in order to be able to use the method which is the case in radiology, manometry, barostat and electromyography. Preparation means previous cleansing of the large intestine which sets the colon into an unphysiologic state. The problems encountered in the specific methods will be discussed.

1. Radiology

In order to visualize colonic contents not only has the colon to be cleansed, but also barium sulphate, an unphysio-

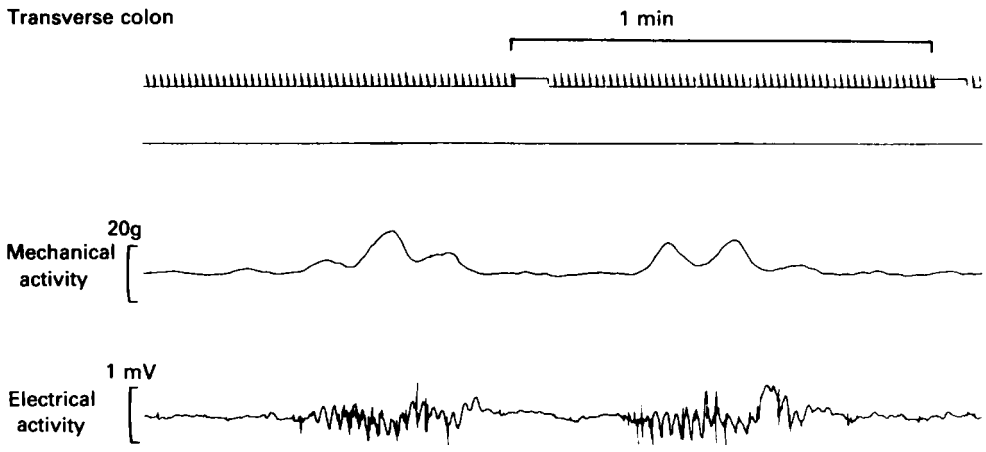

Figure 6: Electrical and mechanical activity in the feline colon. Oscillations are accompanied by sustained contractions.

logic medium, is brought into the large intestine. It is highly unlikely that this can be used to differentiate normal from abnormal colonic motility. In addition, X-ray studies mean radiation exposure which may accumulate to high amounts in the necessarily prolonged observations of colonic movements. But even then the narrow time windows possible in radiology allow only for a restricted assessment of motility in the large intestine. These restrictions are so severe that the method is abandoned nowadays.

2. Manometry

Open-ended or tip catheters pick up a wall movement only when this wall movement leads to a pressure rise. This is the case in most instances, but not in all. If a wall contraction dissipates its pressure changes in adjacent colon segments because of a lack of wall resistance here, i.e. lack of tone and phasic contractions, this contraction will not be picked up by manometry catheters if the contraction does not close exactly over the pressure tip (*Wienbeck*, 1977). Furthermore the previous emptying of the colon under study sets the organ into an unphysiologic state. This is also the case during the immobility of stationary manometry. The ambulant solid-state manometry on the other hand is prone to movement artefacts.

3. Barostat

This is a new method measuring tone, not phasic contractions. So far, it has been used only in the most distal colon. The technique is not yet standardized. Therefore the results may vary from one place to the other. Since the modern barostat is driven by a computer program minor errors may severely affect the results. The method still has other technical problems which may vary from one apparatus to the other.

4. Radioscintigraphy

In order to deliver clear results the method requires cumbersome and long lasting oral intubation. There are only few centres which have sufficient experience with the method in order to make it useful and reliable. Although there is some radiation exposure to the subject under study, this is minimal in relation to that of X-ray studies. The method deserves broader use.

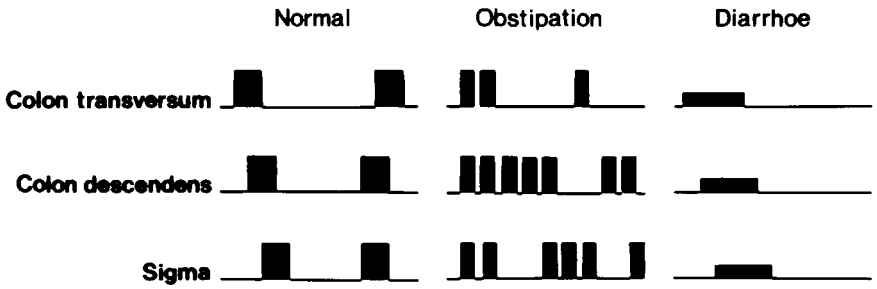

Figure 7: Schematic illustration of the myo-electrical burst activity in the colon during normal circumstances, constipation (short spike bursts prevail) and diarrhoea (migrating long spike bursts prevail).

5. Marker studies

This method is clinically useful although it delivers only coarse information on 3 parts of the colon. For practical purposes this appears to suffice. Because the method extends over several days it is preferentially done in an ambulant set-up. During this time other gastro-intestinal investigations should be postponed in order not to interfere. The radiation exposure of one flat X-ray plate of the abdomen is negligible in relation to conventional radiology of the colon.

6. Electromyography

Although this method is theoretically the clearest and most exact approach to muscle activity, the method has not attained widespread use. This is due to the difficulties in the interpretation of the records which often exhibit overlapping signals. Computer analysis may help somewhat, but not always. In addition, most spikes are lost between the location of their generation and the recording electrode. The recorded spike activity, therefore, represents only a minor part of all spike activity. The slow waves on the other hand may be covert and overlapped by other myo-electrical signals from the same region or even from other organs. Because of the necessary high degrees of amplification, movement artefacts may show up quite frequently and cause major alterations of the records. Nevertheless, as recording techniques improve rapidly and also computer analysis becomes more refined, the method may see its renaissance soon (Figure 7).

CONCLUSIONS

Although at least six methods of clinical usefulness exist in studying colonic motility, none is suitable for a detailed analysis of colonic motility in all its aspects. Each measures only certain aspects. So far, most methods are not well standardized. They are mainly used for research purposes. Only marker transit in the colon and manometry in the ano-rectum have received widespread attention and also clinical use.

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