Physiological measurement

Computerised method for acquisition and display of gastrointestinal motility data

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Abstract—A computerised system is developed for the acquisition and display of gastrointestinal motility data which utilises a purpose developed software program called ‘PC-motil’, running on an IBM compatible microcomputer. ‘PC-motil’ displays data during collection, writes data to disk file and compresses all data at the end of a study on to a single monitor screen for convenient overview. Any area of interest, in single or multiple channels, may be selected and expanded for detailed examination. This system is tested by the recording of gastric and jejunal motility patterns of 11 healthy volunteers in fasting and fed states. All antral and jejunal migrating motor complexes (MMCs) in fasting studies, as well as all fed motility patterns were recognisable in both ‘compressed’ and ‘expanded’ form. The reproduction of motility patterns by the computer based system was indistinguishable from that of a conventional analogue chart recorder. This computerised system provides a convenient and cost-effective means of acquisition, storage and display of motility data in digital form.

Keywords—Computer, Motility, Signal processing

1 Introduction
GASTROINTESTINAL MOTILITY is the term applied to the coordinated gastrointestinal contractions which are responsible for propulsion of food and secretions through the alimentary tract. The dominant parameter of motility is the migrating motor complex (MMC) which is a cyclical sequence of fasting contractions beginning in the stomach or upper small bowel which migrates towards the colon (CODE and MARLETT, 1975). The function of the MMC is that of an 'intestinal housekeeper' which sweeps chyme residue towards the colon (CODE and SCHLEGEL, 1973). Abnormalities of the MMC may be associated with stasis, bacterial overgrowth, abdominal pain, diarrhoea or constipation (KELLOW and PHILLIPS, 1987).

The diagnosis of motility abnormalities requires expert interpretation of gastrointestinal contraction patterns, inferred from pressure changes within the bowel, which are detected by intraluminal devices and conventionally shown by analogue multichannel chart recorders. Digital techniques of data processing generally have the advantages of reliability and convenience over analogue methods (ROZEN, 1986). Our aim in this study, therefore, was the development of a microcomputer based technique for the acquisition, storage and display of gastrointestinal motility data.

2 Materials and methods
2.1 Design of the Dundee 'PC-motil' program

The software was developed at Ninewells Hospital over a two year interval and was written in the Pascal programming language. In essence, the program was designed to manipulate motility data in digitised form and was organised as a set of individual modules within an integrated environment. Each module was dedicated to a particular aspect of the original task, and was accessed through a menu system, whose selections are as follows:

1. The measure module controls the operation of the analogue to digital convertor [ADC] (vide infra) and feeds the digitised motility data sequentially from analogue input channels to separate files on the hard disk. Conversion of an analogue signal to digital data involves a sampling process, whereby the analogue signal is measured or 'sampled' at discrete regular time intervals rather than on a continuous basis. The analogue signal in the present study originated from intraluminal pressure variations in response to gastric and small bowel contractions. There are up to 14 contractions min⁻¹ (CODE and MARLETT, 1975) and such signals could contain significant frequency components up to 1 Hz. Standard theory of analogue to
digital conversion indicates that sampling frequency \( f_s \) should be at least twice the highest component signal frequency to avoid problems with spurious alias signals (Siler 1965). Although signal resolution improves with increased \( f_s \), so also does the data file size which, in the context of long experimental runs in the present study, could become inconveniently large. Hence, \( f_s \) was chosen as a compromise which allowed both good resolution, necessary for time-domain data processing, and data file of manageable size. Initially, an \( f_s \) value of 10 Hz was chosen which gave very good resolution and, with a three-channel system over a 4h recording interval, generated files of 870 kbytes, which could be conveniently archived on to a 1.2 Mbyte floppy disk. All motility studies were initially carried out at \( f_s = 10 \) Hz. It became clear that more than three channels could be desirable, and so two recorded studies from one individual were fed into the system at \( f_s = 5 \) Hz, to ascertain resolution at this frequency. The cut-off frequency of presampling circuitry was matched to these \( f_s \) values to exclude the production of alias components from noise signals.

The measure module provides a real time signal display on screen during the data collection stage, which is essential for subject monitoring and the evaluation of short term physiological responses.

(2) The display module performs all significant display, processing and measurement of the data after digitisation and storage. This module reads the data files from the hard disk and the user can view all of the data in compressed mode, or 'browse' back and forth in shorter time segments using the cursor keys. Any data segment in single or multiple channels, from a duration as short as 1 min to a complete 'overview' of all data (usually 4h), may be selected for high resolution display by marking its extents with cursors. Hence, this option allows a flexible means of detailed examination of any section of motility signals. Facilities for provision of 'hardcopy' by a printer or plotter are also provided. Limited analysis facilities which are incorporated within this module include:

(a) the ability to obtain a numerical readout of data amplitudes at any time using a cursor, and
(b) the ability to subtract background levels.

The purpose of modules (3) and (4), the delete and rename files, respectively, are self explanatory. While the measure module always places these data files on the hard disk and the user can view all of the data in compressed mode, or 'browse' back and forth in shorter time segments using the cursor keys. Any data segment in single or multiple channels, from a duration as short as 1 min to a complete 'overview' of all data (usually 4h), may be selected for high resolution display by marking its extents with cursors. Hence, this option allows a flexible means of detailed examination of any section of motility signals. Facilities for provision of 'hardcopy' by a printer or plotter are also provided. Limited analysis facilities which are incorporated within this module include:

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2.2 System hardware

Motility signals (tide infra) were digitised by an Amplicon PC-30 12 bit analogue to digital converter (ADC),† which plugs directly into the computer expansion busbar and has a conversion time of 35 μs. The ADC addresses up to 16 multiplexed input channels and has a sampling rate between 0 and 30 kHz.

The microcomputer which received the digitised data and which ran the 'PC-motil' program in these studies was an OPUS £, IBM AT compatible microcomputer,‡ with a 30 Mbyte hard disk. This had an 80286 microprocessor running at 10 MHz and had 1 Mbyte of random access memory (RAM), of which 384 kbytes was available for use as a RAM disk for rapid processing of motility files. A high resolution (enhanced graphics adapted [EGA]) monitor screen was used for immediate graphics display and high resolution permanent hardcopy facilities were provided by a digital plotter.

2.3 System evaluation

The system was assessed against recordings of gastric and small bowel motility in 11 human volunteers, which were evaluated by conventional pressure sensitive radiotlemetry capsules (Remote Control Systems Ltd., 12 Leconfield Road, London, UK). The two radio-pills were calibrated in a sealed container at 37°C, so that a pressure of 50 mmHg produced a full scale deflection on the recording apparatus, and transmitted gastric and jejunal pressure signals at distinguishable frequencies of 350 kHz and 426 kHz, respectively. The signals were detected by separate rod aerials connected to separate radiotelemetry receivers (type 7060). The amplified analogue outputs of the transducers were then fed to the analogue to digital converter (ADC) and thereby processed and displayed on the monitor screen of the central microcomputer.

2.4 Study protocol

The two radio-pills were tethered 50 cms apart to a fine radio-opaque Portex tube§ (with an outer diameter of 1.5 mm). After an overnight fast, all subjects swallowed the radio-pills, which were positioned proximally and distally, under fluoroscopic control, in the gastric antrum and upper jejenum, respectively. Once satisfactory, the position was secured by strapping the Portex tubing to the subject's cheek and motility recordings were taken over four hours in fasting and fed phases. On completion of the fasting studies, the radio-pills remained in situ overnight, and the subjects returned on the following day for the fed phase studies. Radio-pill position was checked by fluoroscopy and pill position was adjusted, if necessary, by gentle traction of the portex tube. The total fluoroscopy screening time did not exceed 30 s in any subject. All subjects were given a standard solid meal comprising 200 g mashed potato, 100 g baked beans and 50 ml water, which has a caloric value of 253 kcal.

In two subjects, signals were fed simultaneously from the radio-pills to a conventional multichannel chart recorder (Rikadenki Mitsui Electronics (UK) Ltd., Surrey, UK), as well as to the microcomputer system, for comparison of recording fidelity. On completion of the fasting and fed studies the radio-pills were removed by gentle traction without undue discomfort.

2.5 Six channel evaluation

The capacity of the system for processing six channels of data was tested by sampling two separate three-channel studies from one individual, digitised at 5 Hz.

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† Amplicon Liveline, Brighton, East Sussex, UK
‡ OPUS Supplies Ltd., Redhill, Surrey, UK
§ Portex Ltd., Hythe, UK
£ OPUS Supplies Ltd., Redhill, Surrey, UK