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ASSESSING MOTILITY THROUGH ABDOMINAL SOUND MONITORING

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Abstract - **This paper presents the results of an investigation into a computerised system for the assessment of gastrointestinal motility through the recording and analysis of bowel sounds. The system described is aimed primarily at monitoring post-operative recovery. Other potential applications such as a clinical aid in the determination of the effects of drugs on the intestinal tract and as a method of improving the objective diagnosis of motility disorders are also outlined.**

I. INTRODUCTION

The association between gastrointestinal activity, or *motility*, and the sounds produced by the intestinal tract has long been recognised [1]. Bowel sounds have commonly been used as a means of detecting obstructions or strangulations of the digestive lumen [2], to monitor post-operative recovery of the abdomen after intra-peritoneal operations [3] and to assess the effects of various drugs on intestinal motility [4]. The method currently employed to monitor these sounds is auscultation which involves using a stethoscope to listen to the abdomen typically in four different locations for a duration of five minutes at each location [5]. This practice is not only time-consuming but also subjective which can lead to inaccurate diagnoses. There are no clearly defined method of distinguishing between different sounds, no reference of what can be considered normal bowel sound activity, and no physiological understanding of the significance of each type of sound. The authors believe that a suitable computerised analysis system can provide a fast, accurate and objective alternative to the current practice.

A number of monitoring methods have been presented previously [6] [7] [8]. One of the most interesting early attempts to assess motility [9] employed an analysis of a visual recording of the sound waves together with a calculation of the sound energy, over thirty second intervals. The method is reported as being beneficial in the recognition of rhythmic characteristics of the sounds and in the objective recording of the sound amplitude. Through simultaneous recording of motility using more conventional methods, such as balloon kymography or fluoroscopy, the fist direct correlation between the sound properties and specific gastrointestinal events was observed. The study [9] also reports the successful application of these methods in the assessment of both physiological and pharmaceutical stimuli on the intestine, and in quantising the effects of prandial activity. A more detailed study [10] recorded sound length, number of sounds per second, amplitude of each sound, length of intervals between sounds, and the sound to silence ratio in a healthy control group and in a group having a variety of motility disorders. It was reported that by employing these characteristics it was possible not only to distinguish between controls and those with acute abdomens but also between different acute abdominal conditions within the study group. This demonstrates how phonoenterography may be successfully applied as a diagnostic aid. Similar results were reported using a system which performed a frequency analysis on the sounds at thirty second intervals to produce a visual record of frequency shifts caused by various intestinal disorders [11].

II. METHODS

The initial investigations by the authors were carried out on a PC-based system as follows; A piezo-electric transducer was taped to the abdomen and sampled at a rate of 4000Hz. The study focused on three areas of the abdomen; the epigastric region between the base of the sternum and the umbilicus, and the right and left lower regions of the abdomen between the umbilicus and the anterior superior iliac spine. Subjects were fasted for twelve hours and bowel sounds were recorded before and after a non-standardised meal. In this way a wide range of normal bowel sounds were recorded. The amplitude, duration, and total number of sounds occurring at different frequencies were calculated. A plot of these properties against frequency per sixty seconds of data was produced in conjunction with the FFT spectrogram. In this way specific sounds could be identified in healthy subjects and the dependence of these sounds on changing intestinal contents and gastrointestinal activity could be analysed.

Clinical tests are currently being undertaken which simultaneously record the sounds from eight sites on the abdomen. These sites have been selected to allow the monitoring of activity specific to the stomach, pylorus, three regions of the small intestine, and the ascending, transverse and descending colon. Sound activity is sampled at 3000Hz per channel. Characteristics of the sounds in each region as well as the normal rhythmic patterns and progressions of the sounds through the abdomen are being analysed using the parameters described above.

III. RESULTS

Normal bowel sounds were found to occur in the frequency range of 100 - 1000Hz having durations which range from 5 to 200msec and widely varying amplitudes. Each of the typical sounds commonly reported by others [1] was found to have easily distinguishable properties of frequency and duration. For example, the "staccato pop" which is one of the most common bowel sounds characteristic of the colon, generally has a frequency of between 500 - 700Hz and a duration of 5 to 20msec. In contrast gastric sounds are grouped between 100 - 400Hz and have longer durations which vary depending on the contents of the stomach.

A more complete assessment of motility is possible by investigating the amplitude, duration and number of sounds in each of the activity/frequency groups described above. The results shown in Figure 1, which displays the total number of sounds recorded over sixty seconds against frequency, illustrates this point. The sounds were recorded after a period of fasting at the epigastric location. The graph shows a peak between 600 - 700Hz. These sounds correspond to contractions in the small intestine. There are very few sounds between 100 - 400Hz indicating a low level of gastric activity. The gastric sounds show greatest activity (4 in 60 secs.) at 275, 300, and 370Hz. This range of peaks spanning more than 60Hz and being centred at approximately 300Hz is typical of pre-prandial gastric activity. Thus from Figure 1 it may be concluded that the stomach is empty and in an inactive state indicating that the interdigestive cycle rather than the digestive cycle is currently dominant. The high number of contractions in the small intestine indicate that the interdigestive cycle is at the end of its two hour period. Analyses of the graphs of amplitude and duration against frequency can provide further information pertaining to motility.

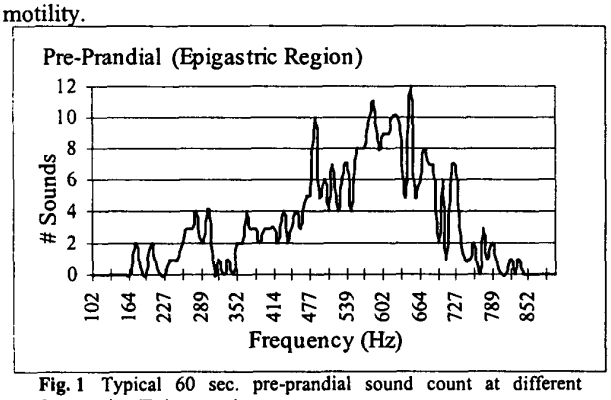

Fig. 1 Typical 60 sec. pre-prandial sound count at different frequencies (Epigastrum).

Ingestion of food was found to have a number of effects on the nature of the sounds. Firstly gastric sounds change in frequency from being in the range of 100 - 400Hz, occasionally peaking at around 300Hz, to being grouped between 350 - 400Hz (Fig. 2). The amplitude of the sounds increases almost immediately after meals and the number of sounds per sixty seconds was also observed to increase slightly. The higher frequency sounds (500 - 700Hz) due to the small and large intestine which may be quite dominant prior to food ingestion if the inter-digestive cycle is at a very active stage, (Fig. 1), immediately reduce in both number and amplitude, (Fig. 2). As the intestinal phase of the digestive cycle begins (approximately two hours after the food is ingested) the intestinal sounds become more prominent.

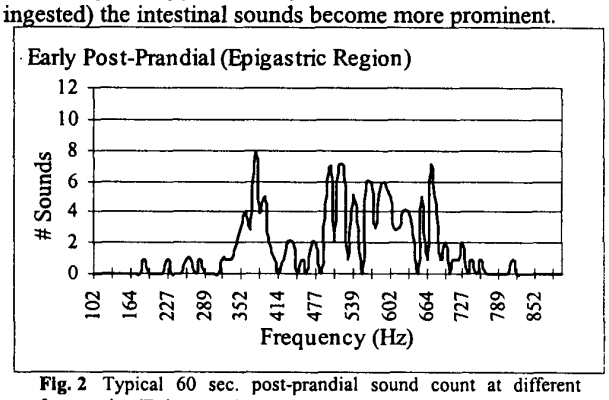

Fig. 2 Typical 60 sec. post-prandial sound count at different frequencies (Epigastrum).

IV. DISCUSSION

Two methods of recording the sound activity commonly used by others have been through counting the total number of sounds, usually as sounds occurring per minute [8], or as a frequency spectrogram of consecutive selected durations of time [11]. While the former successfully records the number of discrete gastrointestinal events which occur per minute, it has the disadvantage of not discriminating between sounds of different frequencies which represent different gastrointestinal events, and thus provides only a general picture of the level of activity. The latter, however, while it does discriminate between sounds of different frequencies, is dominated by sounds of high intensity which do not necessarily have a greater significance in the assessment of motility. The high intensity sounds of pyloroduodenal origin usually appear most dominant while the more subtle sounds of the small and large intestine, which occur much more often, appear quite insignificant on a spectrogram. Tests undertaken by the authors indicate, however, that these subtle sounds reveal more about gastrointestinal motility than sounds of pyloroduodenal origin. Thus, using software which determines the peak frequencies of each bowel sound, a graph of the number of sounds against their peak frequencies was produced. This removes the bias of sound intensity and is found to be more indicative of gastrointestinal activity since it records both the number of gastrointestinal events and the type of activity occurring.

V. CONCLUSION

From investigations and observations to date it is concluded that the accurate recording of bowel sounds is possible using simple and inexpensive methods. Normal bowel sounds

which are generally described using very subjective terms "rushes", "gurgles", etc. can easily be objectively distinguished by a system employing the sound analysis described above. The various levels of activity of these sounds such as the number occurring per sixty seconds, the amplitude or a change in duration can yield useful information regarding both the contents of the intestinal lumen and the state of motility of the digestive system in the healthy subject (early post-prandial, active inter-digestive, etc.). Current research is focused on the recognition of rhythmic patterns and the progression of sounds through the gastrointestinal tract. By employing these methods to give a comprehensive indication of intestinal motility, the non-invasive system may be applied to any clinical situation where the motility needs to be assessed such as; monitoring of post-operative recovery, assessing the effect of certain drugs on the digestive system, and as a diagnostic tool which may aid in the identification of intestinal conditions such as pathological ileus, carcinomatous peritonitis, Crohn's disease and appendicitis.

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