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Optimal direction of the electrogastrographic signal in man

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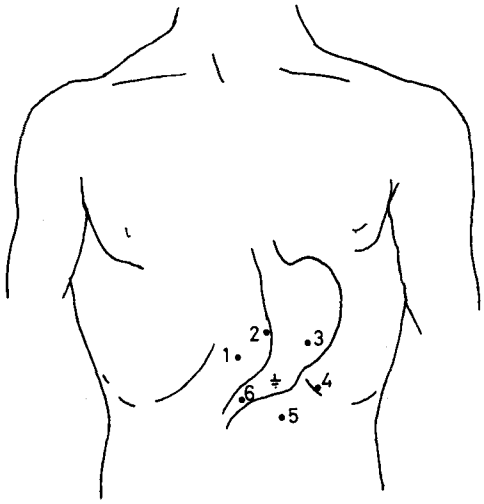
Abstract—*The study aims at determining a characterising configuration useful in obtaining the gastric signal of man from cutaneous electrodes. To do this, a daisy-chain electrode was placed on the abdominal surface making sure that a configuration was on the direction of the antral axis previously defined. The study is based on the analysis of the electrical signals recorded from 13 healthy subjects whose antrum position had been determined by X-rays. In the analysis the gastric signal amplitude was wider in the configuration corresponding with the antral axis than on other ones.*

Keywords—*Electrodes mapping, Electrogastrographic signal analysis*

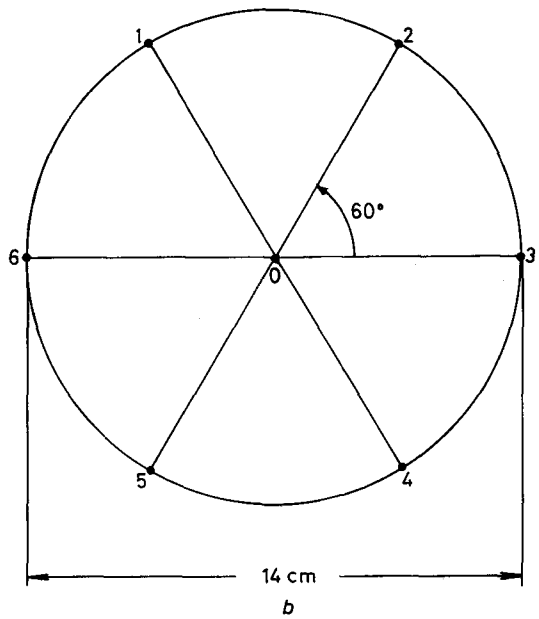
1 Introduction

THE surface abdominal electric signals due to gastric activity were first studied by ALVAREZ (1922). The method of analysis has been called electrogastrography (e.g.g.). BROWN *et al.* (1975) made simultaneous recordings from the surface and mucosal suction electrodes attached to a nasogastric tube and deduced that the signals detected by surface electrodes arose from the b.e.r. (basic electrical rhythm) of the stomach. These results are in agreement with those obtained from our group (GIORGIO *et al.*, 1981).

In these studies the correspondence between the signals picked up by the electrodes *in vivo* placed in the



a



b

Fig. 1 (*a*) *Position of electrodes on the abdominal surface* (*b*) *Geometrical configuration of electrodes*

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muscular longitudinal layer of the gastric antrum and those detected by cutaneous electrodes disposed according to THOUVENOT's (1976) configuration has been verified.

From experiments performed on dogs, SMOUTH *et al.* (1980) explained what is measured by the e.g.g. and proposed a model which describes the electrogastrogram as a result of the field potentials generated by polarisation and repolarisation dipoles. The purpose of this work is to discover whether there is a direction characterising the electrogastrographic signal in relation to a morphologic parameter of the stomach: the antral axis.

The work has been carried out in two parts:

(*a*) ascertaining that the signal picked up originated from the antrum

(*b*) determination of the optimal electrode configuration for detection of the electrogastrogram.

2 Material and methods

Thirteen healthy (eight females and five males) subjects between 15 and 53 years old were studied.

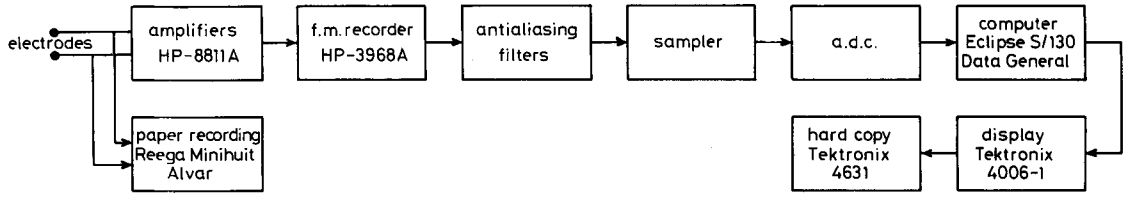

Fig. 2 *Acquisition and processing block diagram*

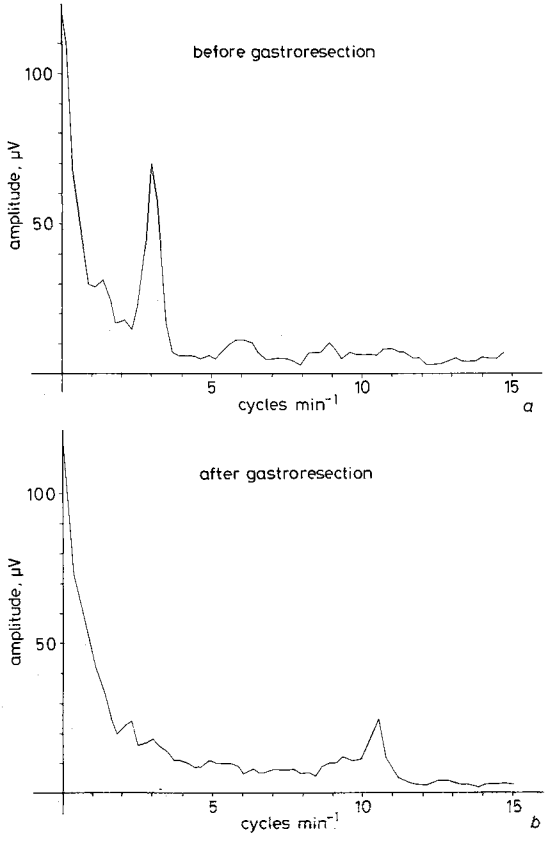

Fig. 3 *Frequency analysis of 1 h recording from cutaneous electrodes placed in the gastroduodenal area, (a) before and (b) after gastroresection*

The measurements made to determine the optimal configuration for detection of the electrogastrogram were preceded by drawing the antral axis. To do this, a solution of 50 ml of gastrografin and 50 ml of water was administered to each subject fasting from the day before. This procedure ensured a good radiographic contrast with a small gastric dilatation.

Then, for each subject (supine), the stomach was localised using X-rays. After this, the organ projection was traced on the abdominal surface and the stomach axis was plotted with a dermatographic pen, according to the indications of BOIRON *et al.* (1978).

All measurements reported in this paper were made with daisy electrodes (General Electric) 12 mm in diameter arranged in a daisy-chain as in Fig. 1 and making sure that the direction 3–6 coincided with the antral axis. A sensor was also placed on the thorax of each subject to monitor respiration.

To ensure a good consistent electrical contact, the skin was mildly abraded and electrolyte paste was applied under each electrode. The subjects rested supine during the recording session which lasted for 1 h.

The analysis of the signal was performed by means of the f.f.t. (fast Fourier transform) using the Welch method, taking 256 samples (frequency discrimination 0·0039 Hz) with an overlap of 50%. Fig. 2 shows the block diagram of the acquisition and processing chain.

The signals were recorded at a speed of 11·9 mm s^{-1} after bandpass filtering (0·02–0·5 Hz cut-off frequency) and amplification. The acquisition rate was 32 times greater.

This approach allowed the use of antialiasing filters with a 12·8 Hz cutoff frequency. It was possible to sample at 32 Hz, thus reducing the acquisition time.

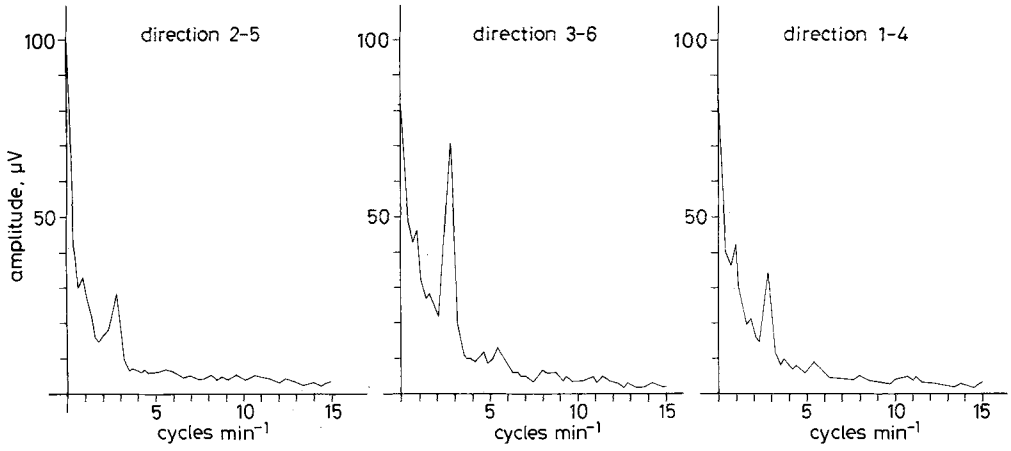

Fig. 4 *Amplitude spectrum of signals simultaneously detected from directions* 2–5, 3–6 *and* 1–4

3 Results

The signal spectrum before and after gastroresection was compared in two subjects. It was observed that, if the stomach is removed, then the e.g.g. signal disappears.

Fig. 3 shows the signal spectrum, obtained through electrodes arranged in the same configuration, on the same subject before and after surgery. The spectrum obtained after surgery, shown in Fig. 3*b*, shows that the frequency peak at 3 cycles min^{-1} disappears. This experiment confirmed that the electrical activity in the stomach is localised in the antrum and in the distal corpus, as reported by other authors (KELLY *et al.*, 1969; WEBER and KOHATSU, 1970; SARNA *et al.*, 1972, 1976).

The analysis of the signal recorded from 13 subjects always showed the same rhythm in the range 2·3–3·2 cycles min^{-1} on all the three directions. However, the amplitude was greater on the 3–6 direction corresponding to the previously defined antral axis. Fig. 4 shows the average spectrum of the signal picked up in the three directions during the 1 h recording.

The characteristic was evident in all cases except two, as shown in Fig. 5. The mean figures are for 1 h of recording.

The Wilcoxon's matched-pairs signed-ranks test confirmed that the antral axis is optimal to characterise electrogastrographic signal in man. This test revealed that the amplitude detected from the direction 3–6 differs significantly ($p < 0{\cdot}01$) from the amplitude detected from the 1–4 and 2–5 directions. Sample traces of the signal obtained from a subject on recording paper are shown in Fig. 6.

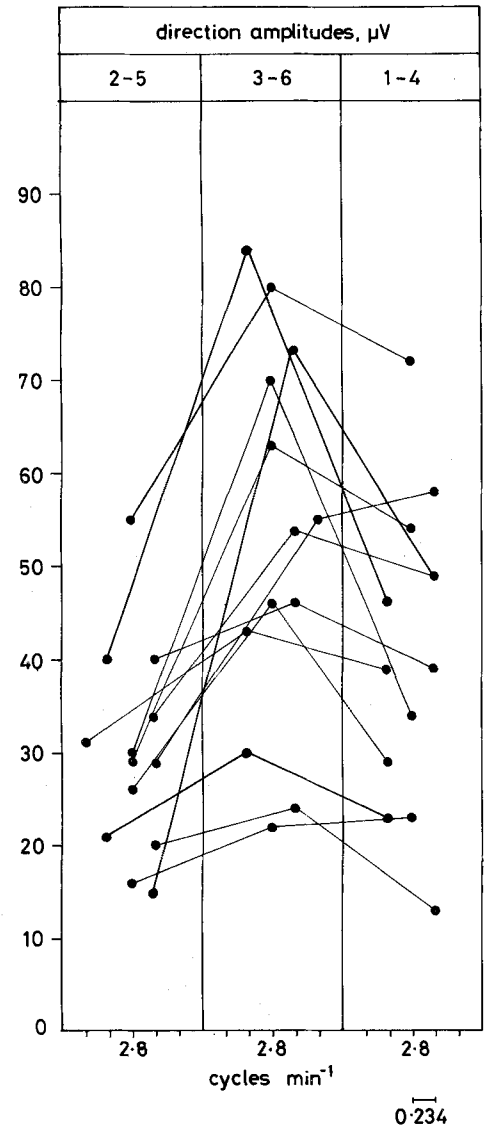

Fig. 5 *Amplitude plot of electrogastrographic signals detected from the three directions*

4 Discussion

The results obtained have confirmed that there is an electrode configuration characterising the electrogastrographic signal in man and that it coincides with the antral axis. Moreover, our study has also shown that, in some cases, the signal detected with the 1–4 configuration is appreciable even though it has been of smaller amplitude and has presented a less neat spectrum compared with the 3–6 configuration.

It has also been found that the signal detection from the 1–4 configuration improves when the antral morphology is *J*-shaped. In fact, in the case of *J*-shaped stomachs, the 1–4, as well as the 3–6 configuration, correspond with the antral axis, but

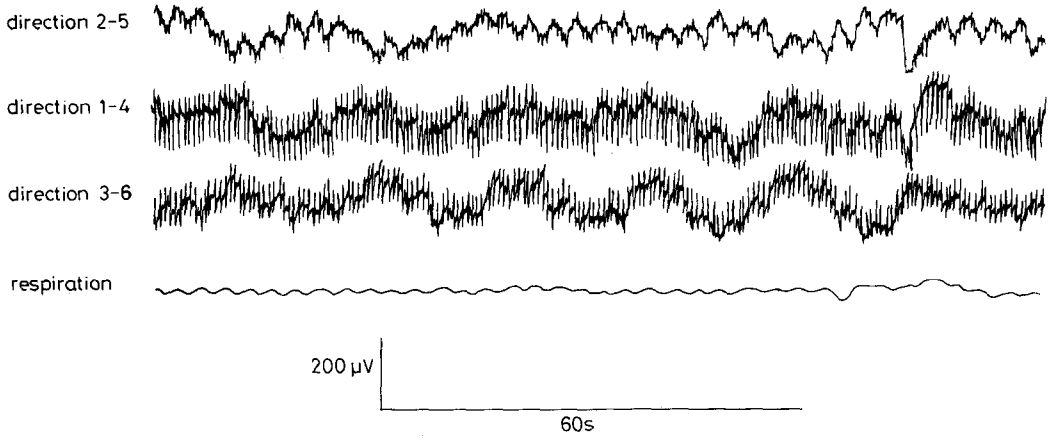

Fig. 6 *Recording made from cutaneous electrodes placed as in Fig. 1*

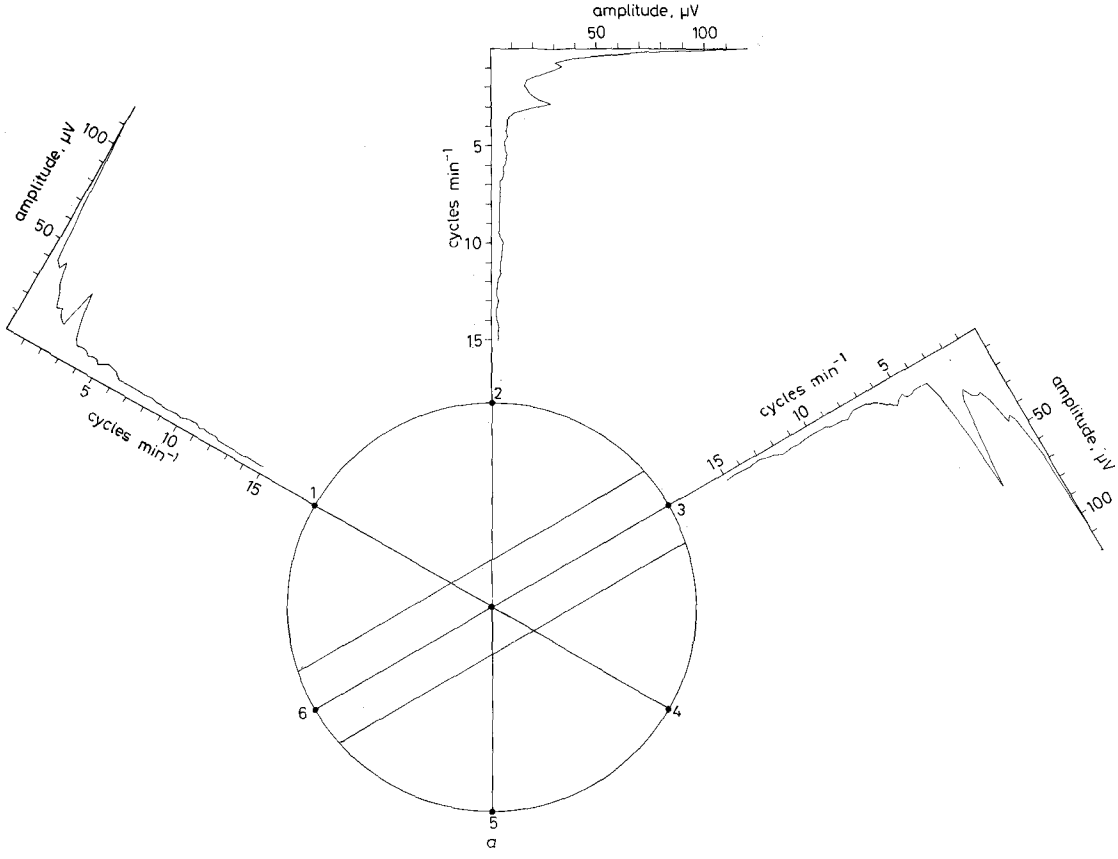

Fig. 7 *Spectral plots for the three directions (a) for steerhorn type stomach,*

Fig. 7 cont. opposite

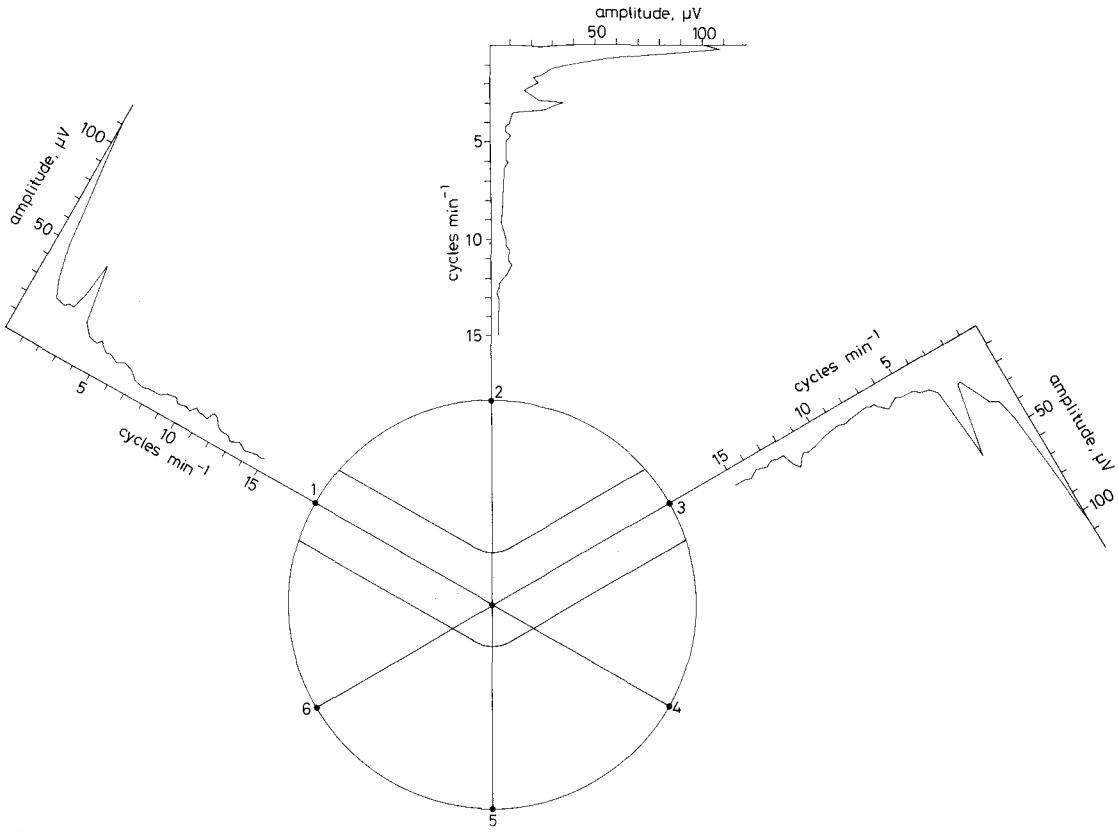

Fig. 7 *(b) for J-shaped stomach*

with a different direction (Fig. 7).

The different amplitudes found with the 3–6 configuration from different subjects (shown in Fig. 5) are due to the following factors:

(*a*) different body mass of the subjects, with consequent different signal attenuation. In this regard the attenuation of the abdominal wall was found to be in the range of 10–80 times as a function of the body mass in the frequency range 0·03–20 Hz and above

(*b*) stomach motility during the recording time.

Electrogastrographic signal analysis cannot yet be applied clinically. However, we believe that the detection of a characterising direction in relation to the antral morphology can be useful for future research into the possibility of clinical diagnosis.

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References

ALVAREZ, W. C. (1922) The electrogastrogram and what it shows. *J. Am. Med. Assoc.*, **78**, 1116–1119.

BOIRON, M., GAEDAU, C. and THOUVENOT, J. (1978) Etude dynamique et paramétrisation des déformation gastrique. *Biomechanics*, **7**, 45–50.

BROWN, B. H., SMALLWOOD, R. H., DUTHIE, H. L. and STODDARD, C. J. (1975) Intestinal smooth muscle electrical potentials recorded from surface electrodes. *Med. & Biol. Eng.*, **13**, 97–103.

GIORGIO, I., PICCIOLI, E., SCAFOGLIERI, U., MISCIAGNA, G., MIRIZZI, N. and ABBATTISTA, N. (1981) Comparison of gastrointestinal myoelectric activity *in situ* and from abdominal surface in man. Proceedings of the Fourth Annual World Association for Medical Informatics, Strasbourg, 349–353.

KELLY, K. A., COKE, C. F. and ELVEBACK, L. E. (1969) Patterns of canine gastric electric activity. *Am. J. Physiol.*, **217**, 461–469.

SARNA, S. K., DANIEL, E. E. and KINGMA, Y. J. (1972) Simulation of the electric activity of the stomach by an array of relaxation oscillators. *Am. J. Dig. Dis.*, **17**, 299–310.

SARNA, S. K., BOWES, K. L. and DANIEL, E. E. (1976) Gastric pacemakers. *Gastroenterology*, **70**, 226–231.

SMOUTH, A. J. M., VAN DER SCHEE, E. J. and GRASHUIS, J. L. (1980) What is measured in electrogastrography? *Am. J. Dig. Dis.*, **25**, 179–187.

THOUVENOT, J. and PENAUD, J. (1976) Electrosplancnographie. Monographie Surget, Paris.

WEBER, J. and KOHATSU, S. (1970) Pacemaker localization and electrical conduction patterns in the canine stomach. *Gastroenterology*, **59**, 717–726.