Archives of Physiology and Biochemistry
1995, Vol. 103, No. 4, pp. 431-435

1381-3455/95/10304-0431$6.00

NON-INVASIVE ELECTROGASTROGRAPHY
PART 1:
CORRELATION BETWEEN THE GASTRIC ELECTRICAL ACTIVITY IN DOGS WITH IMPLANTED AND CUTANEOUS ELECTRODES

E. Atanassova[1], I. Daskalov[2], I. Dotsinsky[2], I. Christov[2] and A. Atanassova[1]

[1]Institute of Physiology, Bulgarian Academy of Sciences
[2]Laboratory of Biomedical Engineering, Bulgarian Academy of Sciences, Sofia, Bulgaria

ABSTRACT

Experiments were made on dogs with bipolar silver ball-shaped electrodes chronically implanted on the muscle wall of the stomach. The electrical activity of the gastric muscle wall (electrogastromyogram-EGMG) was characterized by slow potential changes during the quiescent period of the migrating myoelectric complex (MMC) and bursts of spike potentials during the activity period of MMC.

Cutaneous (surface) electrodes were placed on the abdominal wall. Waves with a rhythm of 4.5 - 5 cpm were led off by the cutaneous electrodes (electrogastrogram - EGG), simultaneously with the EGMG. The bursts of spike potentials with the slow gastric potentials in the EGMG corresponded to an increase of the amplitude of the waves in the EGG. Good correlation was found between the number and frequency of spike potentials in a group and the wave amplitude in the EGG. EGG recorded on an electrogastrograph designed by us was characterized by low-amplitude waves corresponding to the slow waves during the period of quiescence of MMC and high-amplitude waves corresponding to the bursts of spike potentials during the activity period of MMC.

Therefore it is possible to determine the MMC of the stomach by the changes in the amplitude of the waves in the EGG.

KEY WORDS: *Stomach; electrical activity; cutaneous electrodes; implanted electrodes; MMC*

INTRODUCTION

The electrical activity of the gastric muscle wall is characterized by slow potentials during quiescence and bursts of associated spike potentials during activity (peristalsis).

It is well known that gastric slow potentials precede low-amplitude contractions of the muscle wall. The appearance of groups of spike potentials precedes the increase of the amplitude of the contractile – peristaltic – waves (Papasova *et al.*, 1966). Four phases of the migrating myoelectrical complex (MMC) are established depending on the spike activity (Carlson *et al.*, 1972).

Simultaneous records of gastric electrical activity in dogs with serosal and cutaneous electrodes were made to estimate the EGG signals (Smouth *et al.*, 1980 a; van der Shee & Grashuis, 1983). The same frequency of the slow gastric potentials in the EGG and in the electrogastromyogram (EGMG) was found. However some authors failed to establish changes in the slow wave amplitude in the EGG related to the

Correspondence to: Prof. E. Atanassova, Institute of Physiology, Acad. G. Bonchev Str, BL 23, Sofia 1113, Bulgaria

appearance of spike potentials in the EGMG (Nelsen & Kohatsu, 1968). There are data that EGG could also show the degree of the contractile activity (Smouth *et al.*, 1980 a, Abell & Malagelada, 1988). The changes in the gastric contractile waves corresponded to changes in the EGG (Chen & McCallum, 1991).

The purpose of this work was to obtain dog EGG of good quality that would allow for better assessment of possible correlation between the bursts of spike potentials in the EGMG and the increase of the wave amplitude in the EGG

METHODS

In vivo experiments were carried out on 5 mongrel dogs weighing between 15 and 22 kg. Two bipolar silver ball-shaped electrodes (Papasova & Milenov, 1965) were implanted subserously on the muscle wall of the antral part of the stomach (Fig. 1A). The interpolar distance was about 2 mm. A small incision of the serosa was made and each electrode was placed under the serosa on the muscle wall and sutured there by ligatures. The electrodes were implanted under aseptic conditions and chloralose anaesthesia (100 mg/kg i.v.). The electrode leads were mounted on a plug in a plexiglass cannula. The cannula was exteriorized through a small incision 2 cm right to the median line of the abdominal wall. The electrical activity of the gastric muscle wall was recorded on an electroencephalograph at a paper speed of 4 mm/s and a time constant of 0.3 s. The experiments on 18-h starved animals began between the 2nd and 3rd week after surgery. The dogs were trained to lie quietly on the right side during two - three hours.

Cutaneous (surface) electrodes were placed on the abdominal wall at the beginning of each experiment (Fig. 1B). Conventional electrocardiographic prejelled disposable stick-on electrodes were used. The electrical activity of the gastric wall was recorded simultaneously on the same electroencephalograph using a time constant of 7 s. The amplitude of the slow waves recorded by cutaneous electrodes was measured in mm and transformed in μV. Two sets of data were collected - one with low-amplitude waves during the quiescent period of MMC, and a second - with high-amplitude waves during the activity period of MMC. The data were statistically processed and the means ± SEM were calculated. Hatched meat (200 g) was given to the dogs in some experiments.

Dog electrogastrograms were recorded also on an electrogastrograph designed by us (Atanassova *et al.*, 1995). A method for complete elimination of the cardiac artefact was elaborated and successfully implemented. It consists of a preliminary elimination of the QRS complex, based on its higher amplitude and slope. The eliminated intervals were replaced by linear segments. A subsequent low-pass filtering allowed to obtain high quality EGG signals.

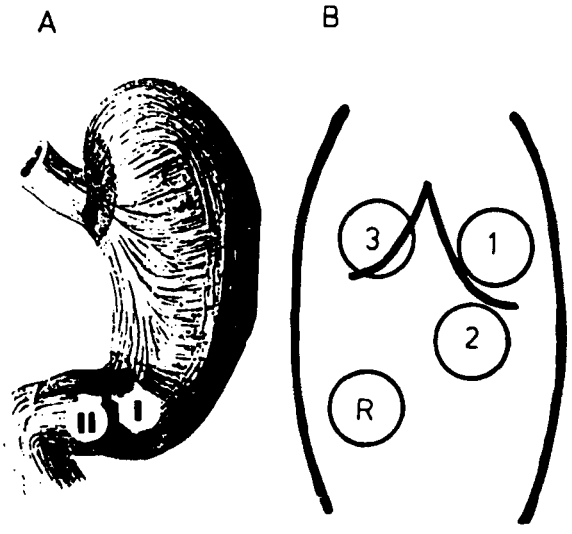

Fig. 1. SCHEME OF THE POSITION OF THE ELECTRODES ON THE ANTRAL MUSCLE WALL OF THE STOMACH.

RESULTS

Simultaneous records of the electrical activity of gastric muscle wall in fasted dogs showed slow waves in the electrogastrogram (EGG) with the same frequency as the slow potential changes in the electrogastromyogram (EGMG) (Fig. 2 A,B). The time correlation was always 1:1. During the quiescent period of MMC when only slow potentials were led off, the waves in the EGG were of low amplitude 236.63 ± 36.03 μV (n=320 from 4 dogs) (Fig. 2A). The appearance of spike potentials with the slow potentials in the EGMG led to an increase of the wave amplitude in the EGG (Fig. 2 B, C). The larger the number of spikes in a group and the higher their frequency, the higher the amplitude of the slow waves in the EGG. The correlation between the appearance of

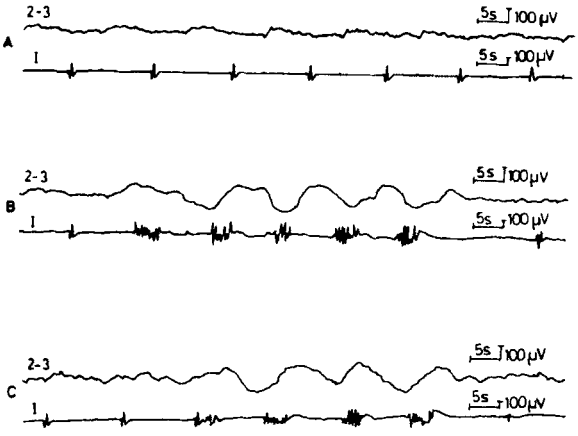

Fig. 2. A. SLOW POTENTIAL CHANGES IN THE EGMG (IMPLANTED ELECTRODE, 2ND CHANNEL) CORRESPONDED TO LOW AMPLITUDE SLOW WAVES IN THE EGG (cutaneous electrodes, 1st channel). B,C. APPEARANCE OF SPIKE POTENTIALS WITH THE SLOW POTENTIALS IN THE EGMG (2nd channel) RESULTS IN AN INCREASE OF THE WAVE AMPLITUDE IN THE EGG (1st channel)

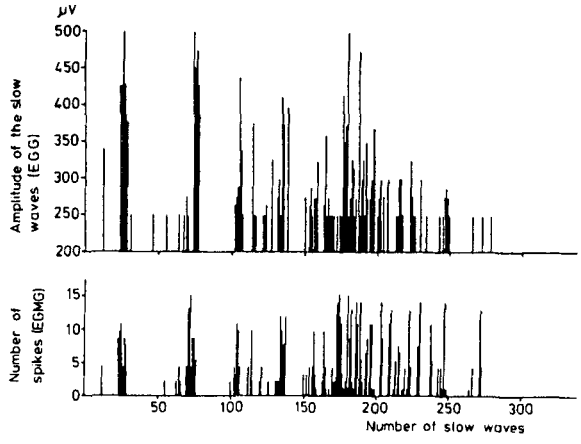

Fig. 3. CORRELATION BETWEEN THE INCREASE OF THE AMPLITUDES OF THE WAVES IN THE EGG (A) AND THE NUMBER OF SPIKES IN A GROUP WITH EVERY SLOW POTENTIAL IN THE EGMG (B) DURING AN ACTIVE PERIOD OF MMC. The amplitude of the slow waves lower than 250 μV are not presented. On the abscissa – number of slow waves; on the ordinate – A: slow wave amplitude in the EGG; B: number of spike potentials in a group in the EGMG.

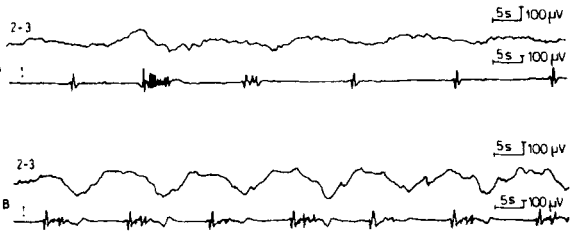

Fig. 4. INCREASE OF THE AMPLITUDE OF THE SLOW GASTRIC WAVES AFTER FEEDING (B). Background activity (A). (record on an electroencephalograph).

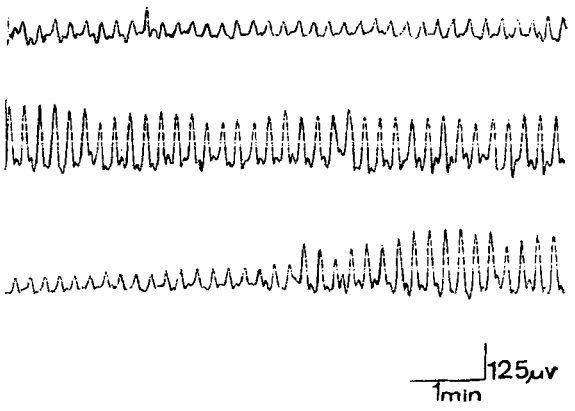

Fig. 5. A RECORD OF DOG GASTRIC ELECTRICAL ACTIVITY BY CUTANEOUS ELECTRODES ON THE ELECTROGASTROGRAPH. A: Low-amplitude slow waves during a quiescent period of MMC. B: Slow waves with higher amplitude compared to that in A, related to the active period of MMC. C: transition from the quiescent to an active period of MMC.

bursts of spike potentials in the EGMG and the increase of the wave amplitude in the EGG was 1:1 in this case. The mean amplitude of these waves was 463.95 ± 57.62 μV (n= 180 from 4 dogs). Statistical significance of the difference between the wave amplitude during quiescence and activity (Student's *t*-test, $p < 0.05$) was found. In dog 3, the difference between the amplitudes of the waves during the active and quiescent period was almost 260 μV. In other dogs, this difference was near or over 200 μV. This makes it possible to differentiate the waves in the EGG during a quiescent from the waves during an activity period by the wave amplitude.

An activity period of MMC in one dog is presented in Figure 3 by the number of spikes with every slow potential. It can be seen that a higher amplitude of the wave in the EGG (A) corresponds to a larger number of spike potentials (B).

After feeding the amplitudes of the slow gastric waves markedly increased (Fig. 4B). This corresponds very well to the bursts of the spike potentials appearing in the EGMG.

The electrical activity of the dog stomach was recorded by cutaneous electrodes on an electrogastrograph designed by us (Atanassova *et al.*, 1995). Low-amplitude slow waves were recorded during periods of 20 - 40 min (Fig. 5A). After these periods with high amplitude slow waves were observed (Fig. 5B). The transition of low-amplitude to high-amplitude waves was evident (Fig. 5C).

DISCUSSION

When comparing the EGG and the EGMG in dogs, authors found the same frequency of the slow potentials (Smouth *et al.*, 1980 a; Abell & Malagelada, 1988). Nelsen and Kohatsu (1968) did not found 1:1 correlation between the EGG and the contractions and they suggested that EGG could not be used to determine when the contractions occurred.

The present data show that the simultaneous records by implanted and cutaneous electrodes were of good quality and can be used to prove correlation between the appearance of spike activity in the EGMG and the increase of the slow wave amplitude in the EGG. In agreement with Oigaard and Dorph (1974 a, b), it was established that the larger the number of spikes in a group and the higher their frequency, the higher the amplitude of the waves in the EGG (compared to that in quiescent periods). This correlation was not always 1:1 because the implanted bipolar electrode led the electrical activity of a small area of the gastric muscle wall while the distance between the two cutaneous electrodes was 3 - 5 cm and they recorded the global smooth muscle activity of almost 1/3 to 1/2 of the stomach.

After feeding the slow wave amplitude in the EGG increased, corresponding to the bursting of groups of spike potentials in the EGMG (Smouth *et al.*, 1980 b).

Dog electrogastrogram, recorded by the electrogastrograph eliminating the cardiac artifacts, was good enough to differentiate low-amplitude and high-amplitude waves on visual inspection.

Thus EGG could provide information about the intensity of contractions of the stomach. The periods with waves of comparatively high amplitude would characterize the active periods, while the periods with low-amplitude waves would express the quiescent periods of MMC.

RESUME

Des expériences sur des chiens ont été effectuées avec des électrodes bipolaires en forme sphérique, implantées chroniquement sur la paroi musculaire de l'estomac. L'activité électrique (l'électrogastromyogramme - EGMG) est caractérisée par des ondes lentes pendant la période du repos du complexe myoélectrique migrant (MMC) et des groupes de potentiels de pointe pendant la période d'activité de MMC. Des électrodes cutanées ont été placées sur la surface de l'abdomen. Des ondes à fréquence de 4.5 a 5 cpm ont été enregistrées par ces électrodes (l'électrogastrogramme - EGG). Les trains de potentiels de pointe avec les potentiels lents de l'estomac ont correspondu à une augmentation des amplitudes des ondes de l'EGG. Une corrélation favorable a été établie entre le nombre et la fréquence des potentiels de pointe d'un train et l'amplitude des ondes de l'EGG. L'EGG, enregistré par des électrodes cutanées, se caractérise par des ondes d'une amplitude basse, correspondant aux ondes lentes pendant la période de repos de MMC et des ondes d'une amplitude haute, correspondant aux groupes de potentiels de pointe pendant la période d'activité de MMC. En conséquence, il a été possible d'identifier les MMC gastriques d'une manière non-invasive par le changement des amplitudes des ondes de l'EGG.

MOTS-CLÉ: estomac; activité électrique; électrodes cutanées; électrodes implantées; MMC

ACKNOWLEDGMENT

This work was supported by grant L-234 from the National Science Foundation, Bulgaria.

REFERENCES

ABELL, T.L. & MALAGELADA, J.R. (1988). Electrogastrography. Current assessment and future perspectives. *Dig. Dis. Sci.* **33,** 982-992.

ATANASSOVA, E., DASKALOV, I., DOTSINSKY, I., CHRISTOV, I., & ATANASSOVA, A. (1995). Non-invasive electrogastrography. Part 2. Human electrogastrogram. *Arch. Physiol. Bioch.* **103,** 436-441.

CARLSON, H., BEDI, B. & CODE, C.F.(1972). Mechanism of propagation of intestinal interdigestive myoelectrical complex. *Am. J. Physiol.* **222,** 1027-1030.

CHEN, J. & MCCALLUM, R.W. (1991). Response of the electric activity in the human stomach to water and a solid meal. *Med. Biol. Eng. Comp.* **29,** 351-357.

NELSEN, T.S. & KOHATSU, S. (1968). Clinical electrogastrography and its relationships to gastric surgery. *Am. J. Surg.* **116,** 215-222.

OIGAARD, A. & DORPH, S. (1974 a). The relative significance of electrical spike potentials and intraluminal pressure waves as quantitative indicators of motility. *Am. J. Dig. Dis.* **19,** 797-803.

OIGAARD, A., & DORPH, S. (1974 b). Quantitative analysis of motility recordings in the human small intestine. *Am. J. Dis.* **19,** 804-810.

PAPASOVA, M. & MILENOV, K. (1965). Method for recording biopotentials from cat gastric muscles with chronically implanted electrodes. *Bull. Inst. Physiol.* **8,** 187-191.

PAPASOVA, M., MILENOV, K., BOEV, K. & ATANASSOVA, E. (1966). Dependence between the appearance of spike potentials in the electrogastromyogram and the intensity of the contraction wave of the gastric wall. *C.R. Acad. Bulg. Sci.* **19,** 241-244.

SMOUTH, A.J.P.M., VAN DER SHEE, E.J. & GRASHUIS, J.L. (1980 a). What is measured in electrogastrogram. *Am. J. Dig. Dis.* **25,** 179-187.

SMOUTH, A.J.P.M., VAN DER SHEE, E.L. & GRASHUIS, J.L. (1980 b). Postprandial and interdigestive gastric electrical activity in the dog recorded by means of cutaneous electrodes. In: Gastrointestinal Motility, J. Christensen, ed. Raven Press **187,** 194.

VAN DER SHEE, E.J. & GRASHUIS, J.L. (1983). Contractile-related low frequency components in canine electrogastrographic signals. *Am. J. Physiol.* **245,** G470-G475.

Accepted: December 8, 1994.