

# RELATIONSHIP BETWEEN INTESTINAL MOTILITY INDEXES FROM INTERNAL AND SURFACE RECORDINGS OF ELECTROENTEROGRAM

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**Abstract**-Electroenterogram is the myoelectric signal of the smooth muscle of the small intestine. This biosignal traduces bowel motility. However, an invasive method is necessary for placing electrodes on small bowel serosa.

The aim of this paper is to relate surface recording spectral parameters of electroenterogram to intestinal motility indexes from internal electroenterogram recordings.

Bipolar electrodes were placed at different points along the small intestine serosa of two Beagle dogs in order to acquire internal myoelectric signals. Likewise two monopolar contact electrodes were situated on abdominal surface for external recording. Internal and surface signals were amplified and acquired simultaneously in fast state. Internal signals were parameterised in order to obtain intestinal motility indexes. In the same way surface recording was quantified to calculate several spectral parameters. Correlation coefficient functions are calculated and considered as results.

Every spectral surface parameter reaches a high correlation with intestinal motility index of each internal recording point. Energy above 2 Hz from the external signal provides highest correlation (round 0.7). Small bowel contractile activity progression referred from abdominal surface recording point is detected. Best correlation is achieved when adjusting time lags.

The energy over 2 Hz of surface recorded signal can be used to represent intestinal motility.

**Keywords** - Electroenterogram, surface recording, intestinal motility, small bowel.

## I. INTRODUCTION

There are several ways to obtain intestinal motility, but only two are the most extended. Considering that muscular cells must contract for splitting and moving the chyme, a direct method for calculating IM is recording bowel pressure through manometric techniques. However, this method arises several technical [1] and physiological [2] problems.

The second method is based on the myoelectric signal required for smooth muscle cells contractions. The relationship between the electric signal and the mechanical signal is widely accepted [3,4]. Myoelectric techniques consists on recording the electroenterogram by fixing electrodes to small bowel serosa. Electroenterogram is the result of a slow wave (SW) and a spike burst (SB) (fig. 1). The former is always present and does not represent intestinal motility but the maximum rhythm of small bowel contractions (aproximately 5 SW are seen in upper trace in fig. 1). The latter appears when the smooth muscle contracts and indicates moving activity [3,4] (lower trace in fig. 1).

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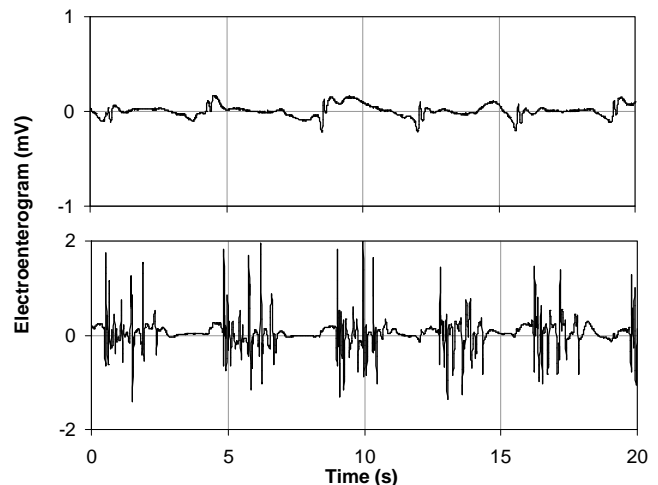


Fig. 1. Electroenterogram in phase I of the IMMC when there is no SB (upper trace) and in phase III of the IMMC when maximum number of SB appear (lower trace)

When a fast period of more than 8 hours is being held, the electroenterogram follows a pattern of activity called interdigestive migrating myoelectric complex (IMMC) (Fig.2). This pattern of activity has also been called *housekeeper* due to his mission of intestinal cleaning [5]. IMMC is divided into three phases. Phase I presents minimum contractile activity, during this phase the ratio of slow waves accompanied by a spike burst is less than 10% (upper trace fig 1). In phase II this ratio has to be higher than 10 % and not greater than 90%. Finally, in phase III, more than 90% of slow waves have an associated spike burst (lower trace fig. 1). Phase III duration is 5-8 minutes and it is the phase with maximum mechanical activity.

Fig. 2 shows two IMMC which are quantified with an intestinal motility index (IMI). This IMI can be defined in several ways depending on the author [3,4,5]

Nevertheless, the application of myoelectric techniques for clinical diagnostic purposes is restraint because surgery is required. A possible solution could be surface recording [6,7]. Electroenterogram captured on abdominal surface has been proved to strongly correlate with internal myoelectric signal [6,7]. Specifically, SB energy measured externally correlates to the SB energy measured in bowel serosa. Fig. 3 shows signals captured simultaneously from internal (upper trace) and external electrodes (lower trace) [7].

The goal of this paper is to relate intestinal motility index (IMI) of internal electroenterograms to spectral parameters from surface myoelectric activity recordings in order to use these surface parameters as new motility indexes.

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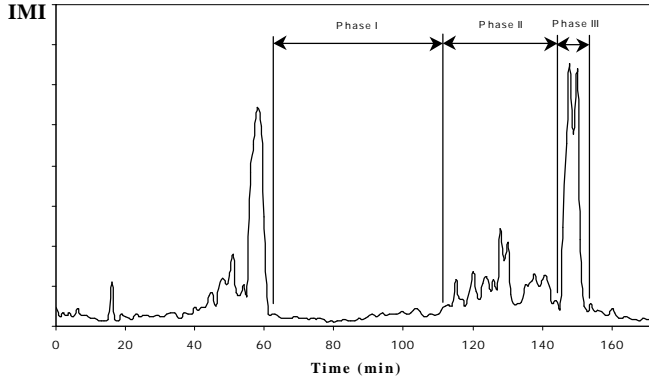


Fig. 2. Two Interdigestive Migrating Myoelectrical Complex (IMMC) recorded at a gut ring in jejunum after 8 hours of fast.

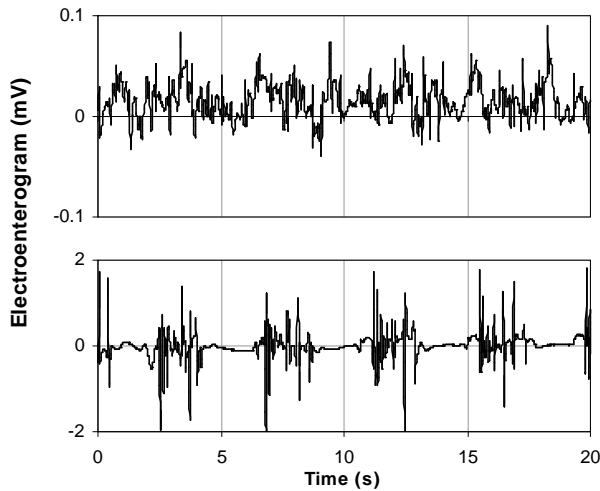


Fig. 3. Electroenterogram acquired on abdominal surface (upper trace) and in small bowel serosa (lower trace) in a period of maximum activity.

## II. MATERIAL AND METHODS

15 record sessions were taken in two Beagle dogs. Six biosignals were acquired in every session. Five bipolar Ag-AgCl electrodes were sutured to small bowel serosa for internal recording, and two monopolar Ag-AgCl contact electrodes for surface recording. Internal electrodes were placed in the duodenum, Treitz angle, and the other three electrodes were distributed along the jejunum. The fourth internal electrode was sutured to internal abdominal wall in order to have a reference of intestine position (jejunum 2).

During recording sessions, external electrodes were placed on abdominal surface (separated 3 cm) in the area over the affixed internal electrode. Recording sessions started after seven days of surgery, carrying out two sessions per week.

All six signals were amplified and band-pass filtered with a bandwidth of [0.05 Hz,35 Hz]. The DAQ system is constituted by a PC, a 12 bits ADC acquisition board from National Instruments® and a software designed under the program development application LabVIEW® (National Instrument®). Signals were acquired with a sample rate of

100 Hz and subsequently analysed also under LabVIEW® developed software.

Unmodified periodograms were calculated from surface electroenterogram considering 1 minute length of biosignals. Every periodogram has been parameterised by its energy (EF0), its energy over 2 Hz (EF2), mean frequency (FM) and frequency standard deviation (FSD).

In order to obtain IMI from each of the five internal signals, energy in spectral domain is calculated without considering SW of the electroenterogram (EF2) [4]. Myoelectric signals are analysed in spectral domain because frequency content of electroenterogram has been proved to be fundamental for quantifying the intensity of the bowel motility [3,4].

The correlation coefficient functions (CCF) between surface parameters (EF0, FM, FSD and EF2) and motility index (EF2) of the five internal signals were calculated for every session.

$$r_{xy}[k] = \frac{R_{xy}[k] - \bar{x}[n] \cdot \bar{y}[n]}{\sqrt{\left( R_{xx}[0] - \bar{x}[n]^2 \right) \left( R_{yy}[0] - \bar{y}[n]^2 \right)}} \quad (1)$$

for  $k \in [-M, +M]$ . Where  $x[n]$  and  $y[n]$  for  $n=0,1,2...M-1$  are the studied series;  $M$  is the number of minutes analysed in the session;  $R_{xy}[k]$  is the crosscorrelation coefficient of  $x[n]$ ,  $y[n]$  series;  $R_{xx}[k]$  and  $R_{yy}[k]$  are the signals autocorrelation.

Every CCF calculated is defined by its maximum value and its corresponding time lag. Mean and standard deviation study of maximum coefficients and time lags was carried out in order to establish significant differences ( $p < 0.05$ ).

## III. RESULTS AND DISCUSSION

Table I shows mean and standard deviation of maximum values of CCF between surface signal spectral parameters and internal IMI of the different acquisition points. Surface spectral parameters present mean values over 0.5 which implies a high correlation. Surface EF2 presents best correlations with a maximum coefficient mean round 0.7. However, there are no significant differences with FM and FSD parameters. EF0 includes the energy of slow wave, which does not traduce intestinal motility, providing lower correlation values [3,4].

Fig 4 shows correlation coefficient functions between EF2 of surface recording and IMI of internal signals of one of the analysed sessions. The maximum value of CCFs strikes at different points corresponding with different time lags. Fig. 5 shows IMI of internal recordings and EF2 of surface recordings. IMMC progression along the small intestine can be observed. For instance, while duodenum is in phase III of the IMMC, jejunum is still in phase II. Synchronization of IMMC detected on abdominal surface and at the affixed internal electrode (jejunum 2) can also be noticed. These time lags between signals (fig. 5) seem to be related to the time lags of calculated CCF's maximum coefficients (fig 4).

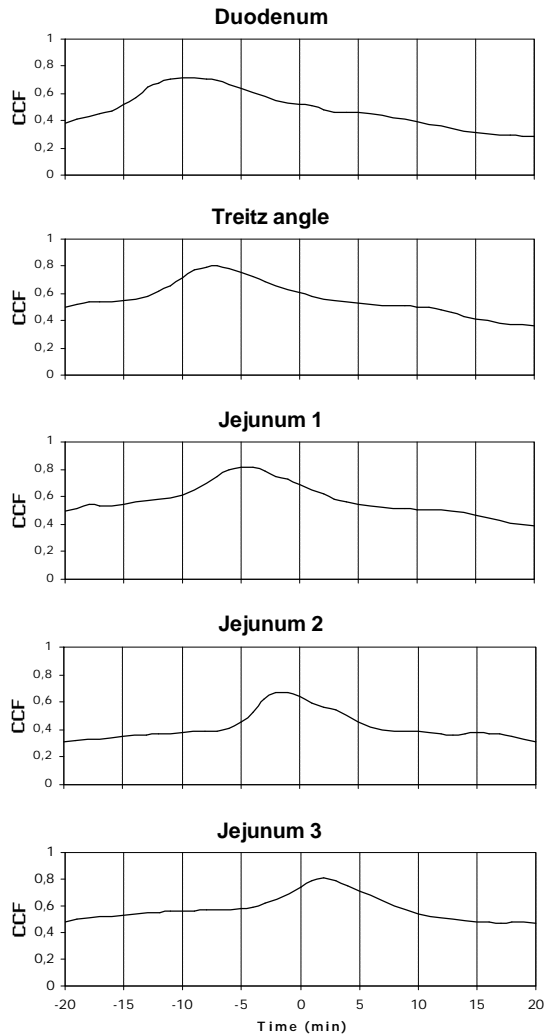


Fig. 4. Correlation coefficient functions (CCF) between EF2 calculated from surface signal and internal signals IMI in a recording session.

Table II shows mean and standard deviation of calculated time lags for EF2 surface parameter. It can be inferred that time lags depend on the distance between internal acquisition point and surface electrodes; i.e. the longer the distance between recording points the bigger the time lag. The duodenum mean value does not follow the tendency, however it presents the highest standard deviation. Sign of time lag indicates relative position to external capturing point; i.e., positive and negative values correspond to downstream and upstream internal acquisition points location respectively.

In table II, standard deviation values are moderately high. The intestine possible movements between sessions can make time lags results not to be very accurate. The fact that jejunum 2 electrode was fixed to internal abdominal wall and used as a position reference for placing surface electrodes justifies its low standard deviation and a mean time lag of -0.2. Results of EF0, FM and FSD surface signal parameters present high variability and are not shown on table II.

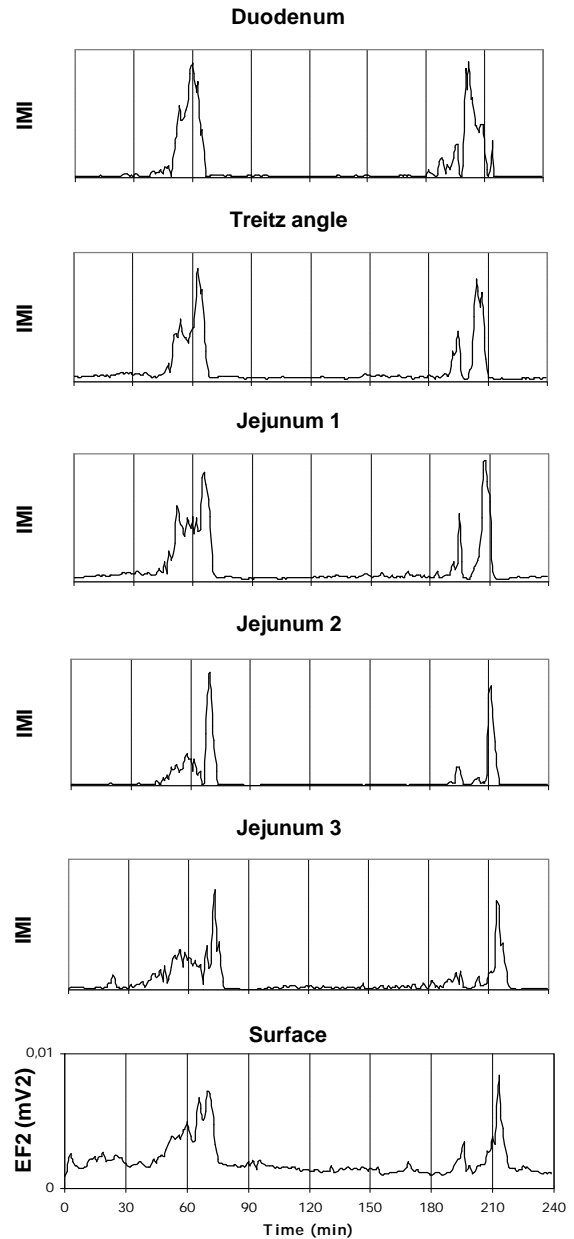


Fig. 5. EF2 parameterised from surface biosignal (lower trace) and IMI from internal biosignals during same session as fig.4.

TABLE I  
MEAN  $\pm$  SD OF THE MAXIMUM VALUE OF THE CORRELATION COEFFICIENT FUNCTIONS BETWEEN SPECTRAL PARAMETERS OF SURFACE RECORDED ELECTROENTEROGRAM (ROWS) AND EF2 OF ELECTROENTEROGRAM ACQUIRED AT DIFFERENT POINTS OF SMALL BOWEL SEROSA (COLUMNS). (N=15)

	Duodenum	Treitz	Jejunum1	Jejunum2	Jejunum3
EF0	0.57 $\pm$ 0.13	0.73 $\pm$ 0.16	0.63 $\pm$ 0.13	0.59 $\pm$ 0.12	0.53 $\pm$ 0.12
FM	0.62 $\pm$ 0.10	0.72 $\pm$ 0.18	0.68 $\pm$ 0.08	0.63 $\pm$ 0.11	0.56 $\pm$ 0.11
FSD	0.61 $\pm$ 0.10	0.73 $\pm$ 0.19	0.65 $\pm$ 0.09	0.60 $\pm$ 0.12	0.53 $\pm$ 0.12
EF2	0.69 $\pm$ 0.12	0.77 $\pm$ 0.14	0.80 $\pm$ 0.07	0.77 $\pm$ 0.10	0.70 $\pm$ 0.14

TABLE II  
MEAN  $\pm$  SD OF THE TIME LAGS OF THE CORRELATION COEFFICIENT FUNCTION'S MAXIMUM COEFFICIENTS BETWEEN EF2 OF SURFACE RECORDED ELECTROENTEROGRAM (ROW) AND EF2 OF ELECTROENTEROGRAM ACQUIRED AT DIFFERENT POINTS OF SMALL BOWEL SEROSA (COLUMNS). (N=15)

	Duodenum	Treitz	Jejunum1	Jejunum2	Jejunum3
EF2	-4.3 $\pm$ 8.0	-5.5 $\pm$ 3.4	-3.0 $\pm$ 2.3	-0.2 $\pm$ 1.1	2.1 $\pm$ 3.7

This paper is in agreement with other authors who defend the presence of small intestine myoelectric activity in surface recordings [6, 8]. They have related small bowel myoelectric signal with external recordings. However, these external recordings of electric [6] and magnetic signals [8] can only detect SW that does not traduce intestinal motility [3,4]. In this study, it is presented a recording system from abdominal surface which could be used for quantifying intestinal mechanical activity.

#### IV. CONCLUSION

This paper shows that small bowel contractile activity can be represented by spectral parameters of myoelectric signal surface recording. Energy over 2 Hz of external signal could be used as an IMI which does not need surgery intervention.

Time lags study results suggest the possibility of being able to calculate the location of the intestine area which contractile activity has been externally measured. In any case, at present, an internal signal is needed for this calculus.

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