ISSN 1870-4069

Colon and Gastric Motility Discrimination by Electrical Bioimpedance

F.M. Vargas Luna[1], M.R. Huerta Franco[2], J.M. Balleza Ordaz[1], I. Delgadillo Holtfort[1], A. Morales Lona[1]

[1] Universidad de Guanajuato,
División de Ciencias e Ingeniería,
Departamento de Ingeniería Física,
Mexico

[2] Universidad de Guanajuato,
División de Ciencias de la Salud,
Departamento de Ciencias Aplicadas al Trabajo,
Mexico

mvargas@fisica.ugto.mx

Abstract. The Electrical Bioimpedance (EBI) has been used for gastric activity monitoring as an alternative to electrogastrography (EGG). The signal obtained by this technique has interference from all other motility signals from the gastrointestinal region, mainly the colon. This is because the colon motility appears in a frequency range that overlaps with that for the gastric frequency range. In fact, EGG technique has the same problem, but this is usually considered negligible and many times is not considered in the discussion. The main objective of this investigation is to elucidate if it is possible to discriminate, with simultaneous measurements in the abdominal region, both mechanical activities by non-invasive electrical bioimpedance technique.

Keywords: colon, motility, bioimpedance.

1 Introduction

In recent years, the electrical bioimpedance (EBI) has been used to evaluate and monitor the gastric motility as an alternative of electrogastrography (EGG). Both techniques seem to be complementary each other because EGG detects electrical activity and EBI detects conformational changes (motility). Electrical impulses not always trigger the gastric motility, but also not all the abdominal movements are produced by normal gastric functioning. In any case, both EGG and EBI have the influence of other abdominal phenomena as those coming from large intestine and colon.

The general assumption is that frequency range discrimination is enough to separate the motility features of each gastrointestinal (GI) region. In this way, gastric frequency motility is considered normal if it lays between 2 and 4 cycles per minute (cpm).

Large intestine motility is considered normal in the range from 7 to 12 cpm, that overlaps with tachygastric frequency range (considered from 4 to 9 cpm) and colon frequency range is normal between 3 and 6 cpm that overlaps with normogastric and tachygastric frequency ranges. Most of the literature is focused mainly in gastric region but colon motility is scarcely discussed and is considered negligible as the gastric signal is obtained very close to the gastric region [1]. In this vein, the colon motility, detected in the lower part of the abdominal region, should bear the same situation relative to the gastric motility interference.

EBI is based in the evaluation of the opposition to an electrical current (impedance in the case of alternate current). Any change in the internal configuration either in density, material content, conductivity of the internal fluid or material conformation yield to a change in the electrical impedance of the tissue, organ or body region. The technique is very common in clinic for PH measurement, in cardiology to evaluate cardiac output and body composition to get percentage of body fat [2], among others. Recently, some research has been performed in pulmonary ventilation [3] and gastric motility [4] using EBI.

In general, GI monitoring has used EBI in endoscopic PH measurement. Large intestine and colon have been also studied using intraluminal catheterization [5], and with a new Capsule-Based device [6]. In addition, the rectum has been studied by EBI using invasive internal devices to get information about filling and motility in an animal model [7]. In this last case, for humans, the impedance planimetry in combination with the use of an intraluminal balloon gives information about the mechanical properties of the rectum walls [8-10]. An attempt to use EBI in a non-invasive way to get information about the rectal filling was performed in 1998 using a phantom getting poor results [11]. In any case, EBI is not considered as an emerging method for intestinal motility evaluation [12]. The external, non-invasive, detection of the colon motility has been searched scarcely.

Due to this gap in the use of EBI technique to get information about the colon performance, it is necessary to evaluate the feasibility of the use of simultaneous gastric and colon EBI monitoring to discriminate colon motility.

2 Methodology

Subjects: Twenty-three subjects were recruited and evaluated during the morning (before noon) regardless the age, or fasting conditions. All the volunteers were questioned about their recent GI health or chronical diagnosed diseases related to GI system or any other condition affecting collaterally the GI function. Since this is a correlational study between two simultaneous signals of the same subject around the same body region, we did not ask for any particular condition (fasting, previous activities, habits etc.) but for being healthy mainly regarding GI health. In fact. the diversity of situations presumably would lead to a reinforcement of the conclusions about the possible colon motility discrimination.

Procedure: Eight electrodes were placed to each subject, four in the gastric region and four at the level of the colon. The gastric ones were placed two in the abdominal region, one in the midpoint between the umbilicus and the xiphoid process and the second at 5 cm toward the upper left.

The other two electrodes for the gastric measurement were placed in the back at the same level of the abdominal ones avoiding the spinal cord toward the left. The colon electrodes were placed in the horizontal plane, 5 cm below the umbilicus, at the vertical level of the gastric electrodes. All these electrodes were connected to a pair of EBI BIOPAC modulus that injects a 0.4 mA, 50 kHz alternating current. The two injection electrodes were one from those of the front and one from those of the back for each case (gastric and colon). The voltage or measurement electrodes were the other two in each case, the other from the front and the other from the back. After 5 minutes of resting, the simultaneous recording of 30 minutes at rest at 250 samples per second, was performed using the software Acknowledge 3.0.

Statistical Procedure: The raw data was decimated by a factor of 5 to work with 50 samples per second and smoothed to avoid sudden instantaneous extreme values (lasting less than 2 seconds) of the signals. After that, the data was filtered by wavelets (Daubechies Db3 waveform) from 0.008 (0.5 cpm) to 0.15 Hz (9 cpm). The frequency spectra were obtained using FFT and RSA (running spectral analysis with 3.5 min periods and 70% overlapping). The dominant frequency (DF) and the dominant power (DP) as well as the percentage of brady-, normo-, and tachy-gastric motility in either time or number of waveforms, were obtained.

Gaussian decomposition of the frequency spectra is performed to obtain the main frequency components of the motility.

Average of normal range parameters are considered for comparison: i) Dominant frequency (DF) in cpm (Taken from gaussian decomposition analysis). ii) Dominant Power (DP) in Watt/Hz. and iii) Proportions of slow waves in brady- normo- and tachy-gastric region in number of waves (Nb, Nn, Nt respectively) and time (Tb, Tn, Tt respectively).

3 Results

The main parameters considered from frequency domain are dominant frequency and power. Dominant frequency was taken as the average value of the peaks appeared in the normal range weighted by the relative area under the corresponding gaussian waveform. The dominant power was taken from the absolute height of the main peak in the normal range (see Table 1). In time domain, the proportion of bradygastry, normogastry and tachygastry activity based in number of slow waves or time spend in each activity region are also recorded (see Table 2). These proportions were obtained from the filtered slow waveforms from 1 to 9 cpm.

Several of these variables do not have normal distribution, so non-parametric Wilcoxon signed-rank test was performed to compare paired data.

Dominant frequency is the same in both gastric and colon regions regarding the normal frequency range, but dominant power in this frequency range is significantly lower in the colon region.

The normal slow waves are significantly lower in colon evaluation, however bradygastric and tachygastric events are higher in average without reaching the statistical significance.

Table 1. Frequency domain parameters: Mean dominant frequency and power obtained from the gastric and colon evaluation.

	Gastro	**Colon**	**Wilcoxon signed-rank test: p**
Dominant frequency in the normal region (cpm)	2.7 ± 0.5	2.8 ± 0.6	0.97
Dominant power in the normal region (W/Hz)	7.4E-3 ± 1.4E-2	1.9E-5 ± 3.4E-5	0.003

Table 2. Time domain parameters: Mean proportion of bradygastry, normogastry and tachygastry based in number of slow waves (Nb, Nn, Nt respectively) or time spend in each activity region (Tb, Tn, Tt respectively).

	Gastric	**Colon**	**Wilcoxon signed-rank test: p**
Nb	0.07 ± 0.05	0.09 ± 0.06	0.153
Nn	0.8 ± 0.07	0.76 ± 0.06	0.052
Nt	0.13 ± 0.07	0.15 ± 0.06	0.153
Tb	0.11 ± 0.07	0.13 ± 0.08	0.201
Tn	0.81 ± 0.07	0.77 ± 0.06	0.048
Tt	0.08 ± 0.05	0.10 ± 0.07	0.201

4 Discussion

EBI is a technique that can detect changes in the material under study. In particular, conformational changes yield in changes in the EBI. In this vein, the gastric and colon motility can be monitored by EBI. The low dominant power detected in the colon region in the normal frequency range could be due to the distance from the main source of this movement that is placed in the gastric region, although 2-4 cpm is included in the colon motility range.

The difference in subcutaneous fat is also a factor that could contribute to this difference, but the two order of magnitude in the average power could not be explained entirely by this factor. Local body fat parameters should be studied in detail in future research to quantify this factor. The decrement in normal waveforms in colon evaluation is compensated by the small increment in both brady- and tachygastric motility detected by colon region electrodes in average although not statistically significant.

These results could be interpreted as the increment in the motilities lower than 2 cpm or larger than 4 cpm in the colon region. Is worth to mention that tachygastric waveforms percentages for colon and gastric regions correlate positively (R=0.46, p=0.03). This means that the changes in this frequency region are more significant and both sets of electrodes are sensitive of these changes. However, tachygastric contribution is lower in gastric region than in colon.

5 Conclusions

The monitoring of EBI in the gastric and colon region gives a significant difference in the normogastric parameters. The percentage of slow waves in the normal range is significantly higher in the gastric monitoring. This change is compensated by the mean changes, although without statistical significance in low and high frequency motility detected by both sets of electrodes. The tachygastric motility is detected by both sets of electrodes and correlate positively. This gives the bases of the possibility to discriminate the colon motility using EBI technique.

Ethical considerations. The volunteers signed an informed consent before the measurement session. The personal data was completely confidential, and all the procedure was aligned to the ethical regulations of the Helsinki Declaration [13]. The protocol was approved by the Ethical Committee of the University of Guanajuato Mexico (CIBIUG-P20-2018).

Acknowledgements. Authors thank University of Guanajuato for financial support (DAIP 253-2019) and all the volunteers for their collaboration.

References

1. Hall, J.E.: Tratado de fisiología médica, Elsevier (2015)
2. Janssen, I., Heymsfield, S.B., Baumgartner, R.N., Ross, R.: Estimation of skeletal muscle mass by bioelectrical impedance analysis. J Appl Physiol., 89, pp. 465–471 (2000)
3. Balleza-Ordaz, M., Perez-Alday, E., Vargas-Luna, M., Kashina, S., Huerta-Franco, M.R., Torres-González, L.A., Riu-Costa, P.J.: Tidal volume monitoring by a set of tetrapolar impedance measurements selected from the 16-electrodes arrangement used in electrical impedance tomography (EIT) technique. Calibration equations in a group of healthy males, Biomed Signal Proces., 27, pp. 68–76 (2016)
4. Huerta-Franco, M.R., Vargas-Luna, M., Montes-Frausto, J.B., Flores-Hernández, C., Morales-Mata, I.: Electrical bioimpedance and other techniques for gastric emptying and motility evaluation. World J Gastrointest Pathophysiol, 3(1), pp. 10–18 (2012)
5. Ruiz-Vargas, A., Costa, M., Wiklendt, L., Dinning, P.G., Arkwright, J.W.: The use of fiber optic sensing technology with intraluminal impedance catheter for functional gastrointestinal motility disorders. In Australian and New Zealand Conference on Optics and Photonics (ANZCOP) (2015)
6. Wang, G., Filip, D., Poscente, M.D., Andrews, C.N., Mintchev, M.P.: Capsule-based measurements of gastrointestinal impedance. Living reference work entry, Handbook of Biochips, pp. 1–14 (2015)
7. Rullier, E., Fioramonti, J., Woloszko, J., Bueno, L.: Electrical impedance, a sensory system for detection of rectal filling after anorectal reconstruction. Dis Colon Rectum, 44, pp. 184–191 (2001)
8. Dall, F.H., Jørgensen, C.S., Houe, D., Gregersen, H., Djurhuus, J.C.: Biomechanical wall properties of the human rectum. A study with impedance planimetry, 34, pp. 1581–1586 (1993)

9. Andersen, I.S., Michelsen, H.B., Krogh, K., Buntzen, S., Laurberg, S.: Impedance planimetric description of normal rectoanal motility in humans. Dis Colon Rectum, 50, pp. 1840–1848 (2007)
10. Krogh, K., Ryhammer, A.M., Lundby, L., Gregersen, H., Laurberg, T.S.: Comparison of methods used for measurement of rectal compliance. Dis Colon Rectum, 44, pp. 199–206 (2001)
11. Ratani, R.S., Yazaki, E., Maw, A., Pilot, M.A., Rogers, J., Williams, N.S.: Pelvic bioelectrical impedance measurements to detect rectal filling. Physiol Meas, 19, pp. 527–534 (1998)
12. Grønlund, D., Poulsen, J.L., Sandberg, T.H., Olesen, A.E., Madzak, A., Krogh, K., Frøkjær, J.B., Drewes, A.M.: Established and emerging methods for assessment of small and large intestinal motility. Neurogastroenterol Motil, 29(17), pp. 1–9 (2017)
13. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. JAMA, 310(20), pp. 2191–2194 (2013)