Line Length Feature of the Electrogastrogram for Delayed Gastric Emptying Diagnosis

Şükrü Okkesim[1], Abdullah Al Kafee[1], Mustafa Selman Yildirim[1], Yusuf Kayar[2], Ahmet Danalioğlu[2], Mehmet Aydin[3], Sadık Kara[1]

[1] Institute of Biomedical Engineering, Fatih University, Istanbul, Turkey
[2] Department of Internal Medicine, Bezmialem Vakıf University, Istanbul, Turkey
[3] Department of Nuclear Medicine, Bezmialem Vakıf University, Istanbul, Turkey
e-mail: sukruokkesim@fatih.edu.tr, a_alkafee@yahoo.com, mselmany@gmail.com, skara@fatih.edu.tr ,ykayar@yahoo.com, drahmetdan@yahoo.com, m_aydin@yahoo.com

***Abstract*—Electrogastrography (EGG) is a noninvasive technique to record the gastric electrical activity. In recent years, researchers have proved that EGG has great clinical potentials to evaluate the gastric disorders. However, it has still not been used in clinic to diagnoses of diabetic gastroparesis or some other disorders. One of the reasons of this can be related to methods using for EGG signal analyzing. Normal gastric myoelectrical activity consists of a slow wave or Electrical Control Activity (ECA) and spikes or Electrical Response Activity (ERA) potentials. Although ERA could be responsible for some changes in EGG signals, it is ignored and neither First furrier transform (FFT) based running spectral analysis (RSA) nor can discrete wavelet transform (DWT) reflect the ERA effect. Line length is an amplitude- and frequency-dependent linear feature therefore it reflects the waveform dimensionality changes. The aim of this study was to investigate the line length feature of the EGG whether it has potential for discriminate the healthy subjects (CT) from diabetic gastroparesis (GP) patients and discuss the line length capability to reflect the ERA effect on EGG. For this aim EGG signals were recorded from 20 CT and 20 GP patients who had delayed gastric emptying. The recordings were analyzed and compared in both groups' pre- and post-prandial states. The results we obtained from line length analysis of EGG signals proved that there are significant differences between the GP and CT groups is statistically significant for pre and post-prandial condition (p = 0,0298* for pre-prandial and p= 0,0032* for post-prandial). The proposed method confirmed that line length feature is useful for detecting delayed gastric emptying and using with some other features more successful computer-aided detection system can design.**

Keywords- diabetic gastroparesis; gastric electrical activity.

I. INTRODUCTION

Each organ of gastrointestinal system has tree control mechanism as myogenic, neural and chemical. The myogenic control is accomplished by autonomy electrical activity and for stomach it is called as gastric electrical activity (GAE) [1], [2]. GAE consist of two components as a slow wave or Electrical Control Activity (ECA) and spikes or Electrical Response Activity (ERA). Researchers have studied on finding the natural pacemaker of the GAE and it is well known that the origin of the GAE is in the corpus and propagate toward the pylorus [2].

Electrogastrography is a non-invasive technique to record the GAE and the signals recorded with surface electrodes positioned on the abdominal skin called as Electrogastrogram (EGG). Studies on spectral analysis of EGG and serrosal recording of ECA proved that there is a correlation between ECA and EGG [3], [4]. Therefore, EGG has received significant interest among researchers to promote a diagnostic test for clinic evaluation of patients with unexplained gastric disorders illness such as ulcer, gastroparesis, functional dyspepsia, gastritis, delayed gastric emptying, chronic mesenteric ischemia and other dyspeptic symptoms [5], [6].

The aim of this study was to investigate the line length value of the EGG whether it has potential for discriminate the healthy subjects (CT) from diabetic gastroparesis (GP) patients. Diabetics who have one of the bloating, distension, nausea, or vomiting with delayed gastric emptying are get diagnosis as diabetic gastroparesis. Delayed gastric emptying is a serious condition that can affect the glycemic control and it has diagnosed with a method called as radioscintigraphy. In this method, a patient is asked to ingest a solid meal with radioactive materials and then to stay in a supine position under a gamma camera. After 2 hours if more than 70% of ingested meal remains in the stomach then the delayed gastric emptying diagnosis is done [7], [8]. The application of this technique is not only radioactive but also expensive, and usually limited to very sick patients. Therefore, EGG has great importance to develop noninvasive and low-cost delayed gastric emptying diagnosis method.

Another aim of this study was to discuss the line length capability to reflect the ERA effect on EGG. ECA is not only accepted but also proved as a main part of GAE and it controls propagation and frequency of the contractions. The basic oscillation of omnipresent ECA is 3 cycles per minute (cpm) in humans [3]–[5], [9]. On the other hand, ERA and its nature not clear as ECA as. Although researchers know and declare that occurrence of ERA related to contraction force of the stomach they usually ignored or assumed as absent [10], [11]. The recorded ECA are variable in frequency, amplitude and stability and ERA can be the reason of these variations, at least it should affect. Although the ERA signals occurring in ECA depolarization are not easily recorded using surface electrodes, the clinical

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significance of EGG is based on capacity to reflect these variations.

For these aims 20 GP patients and 20 CT subjects EGG signals were recorded from both groups with respect pre-prandial and post-prandial states and line length value for each one was computed and compared statistically.

II. Material Method

All the medical part-related steps of this study were completed by gastroenterologist and physician in nuclear medicine in Bezmialem Vakif University. Ethics approval was obtained for the study from Bezmialem Vakif University Clinical Research Ethics Committee- Decision No: 71306642/050-01-04/31 and written consent for participation in the study was obtained from all subjects.

All patients had minimum 6-month chronic history. Patient chronic history, complaints and symptoms were examined by gestational diabetes department doctor. Radioscintigraphy test result is dependent on different causes such as meal composition, test time, body position, smoking or non-smoking [12]. Therefore, test protocol was explained clearly to the all participants included from non-smoking subject and provided to adhere to the protocol. Fasting 30 minutes EGG recording was done for each candidate and a 10 minutes' break was given to eat the test meal. After eating the test meal 60 minutes EGG recording was obtained. The test meal consisted two toast bread and one fried egg also 330 ml cherry fruit juice that has 500 kcal (protein, fat, and carbohydrate). After taking the meal, the subjects were not allowed to eat until the test was completed. Radioscintigraphy test and EGG recording was done simultaneously in a quiet, temperature-controlled room at Bezmialem Vakif University for 2 hours. The first image was taken instantly after the meal, with following images were taken every minutes. Delayed gastric emptying diagnosis was done by the nuclear medicine physician after that EGG signals of the patients was included to this study. Although all participants had minimum 6 months' chronic history some of them did not have delayed gastric emptying according to radioscintigraphy test results. EGG signals of these patients were excluded. Same protocol was followed for control subject except from radioscintigraphy test. The control subjects had no past history of gastric dysrhythmia diseases. None of the subjects were taking medications that might affect gastrointestinal motility.

In this study, EGG signals were recorded by 3CPM company devices that have FDA approval. Demographic knowledge of the subjects was given in Table I.

TABLE I. The Demographic Characteristics of the Gastroparesis and Control groups

	Gastroparesis	Control
Gender	F = 13 M = 7	F = 13 M = 7
Age (mean ± stdev)	32,1 ± 3,4	31,1 ± 9,7
BMI (mean ± stdev)	22,25 ± 1,313	22,49 ± 2,121

Three electrodes are used as seen in "Fig. 1". The skin of body site where the electrodes would be placed was shaved to remove the abdominal hair and cleaned before applying the special gel to reduce impedance of the surface-electrode interface. The first electrode was placed in the midline between xiphoid and umbilicus, while the second one was positioned on the left side of the body, between the lower rib and the first electrode. The reference electrode was placed in the left lower quadrant, at the left costal edge. Noises originating from motions artifacts during recording, respiration, electrocardiography and other gastrointestinal organs are an important problem in the evaluation of the EGG signals. Consequently, signal/noise ratio of the EEG is quite lower compared to our biological indices that are why the participants were told not to talk, read and change their position in order to avoid motion artifacts. The obtained signals were digitally stored at a sampling frequency of 4 Hz

Figure 1. EGG electrode placement.

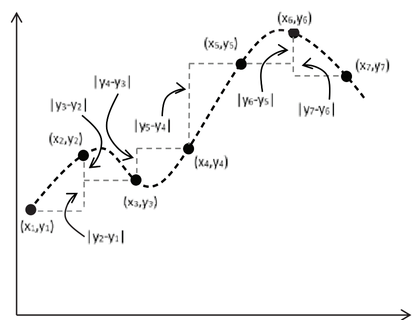

Figure 2. A sample signal and LL computation

For feature extraction purposes, line length method which is sensitive to variations of the signal amplitude and frequency with low computational cost is used for the first time. Line length is reported as a successful method to analyze electroencephalography for seizures detection [13].

As seen from "Fig. 2" and "(1)", line length is computed just sum of the absolute differences between all sequential samples within a predefined window in a continuous manner. Increasing in signal variance or data sequence magnitude will lead to rising of line length value. Therefore, line length can be seen as amplitude and frequency demodulator [14]. The line length is calculated here using the equation below:

$$AverageLineLenght = \frac{1}{N}.\sum_{n=2}^{N}\left|y(n-1)-y(n)\right| \quad (1)$$

where y (n) is the nth sample EGG signal, n is the sample index starting from 1, and N is the number of samples in a session. Total line-length is divided by number of samples to normalize sessions with different lengths, i.e. pre and post-prandial states.

Two-sample t-test was used to determine whether the means of two independent groups as GP and control differ. All the data processing and statistical analyzing was carried out using in-house programs developed under MATLAB R2009b Software (MathWorks Inc., Natick MA, USA).

III. RESULTS AND DISCUSSION

In this study, in order to evaluate the success of line length method to detect delayed gastric emptying, EGG signals were recorded from GP and control subjects and line length values were calculated.

TABLE II. THE COMPARISON BETWEEN THE GROUPS WITH RESPECT TO PRE-PRANDIAL EGG PARAMETERS

Patient no	**Line length for Pre-prandial**		
	CT	***GP***	P value
1	1307,22	1549,17	**0,0298***
2	2280,47	836,38	
3	2103,78	757,76	
4	1589,52	947,60	
5	5569,96	2041,47	
6	1518,84	1293,25	
7	803,74	760,54	
8	1499,05	2895,23	
9	2423,16	3189,49	
10	1341,86	873,69	
11	918,84	1634,75	
12	2178,51	1629,73	
13	1556,25	1405,90	
14	1292,59	1319,71	
15	2205,15	1693,48	
16	3013,76	1755,00	
17	2716,18	694,32	
18	1425,03	1163,99	
19	2697,64	1283,13	
20	2625,14	777,52	
Mean ±Std	2053,34±1042,27	1425,11±679,50	

In reference to Table II and III, means of control group is higher than GP group. This means that variations in amplitude and frequency of EGG signals recorded from control subjects is higher than GP subjects in both pre and post-prandial condition. And, the difference between GP and control group is statistically significant for pre and post-prandial condition (p = **0,0298*** for pre-prandial and p= 0**,0032*** for post-prandial, "Fig. 3, 4").

TABLE III. THE COMPARISON BETWEEN THE GROUPS WITH RESPECT TO POSTPRANDIAL EGG PARAMETERS

Patient no	**Line length for Post-prandial**		
	CT	***GP***	P value
1	1674,42	1116,05	**0,0032***
2	2200,44	892,54	
3	1541,21	1199,79	
4	1576,46	909,94	
5	3882,10	3048,57	
6	1840,37	1456,83	
7	6047,08	883,06	
8	2349,60	2166,72	
9	2964,66	4759,20	
10	2052,56	201,81	
11	962,29	1162,72	
12	2789,37	1428,02	
13	2323,92	1536,40	
14	1283,42	2567,39	
15	2148,38	1458,27	
16	3393,62	1746,94	
17	4034,23	1120,51	
18	2664,16	1497,09	
19	3575,00	955,69	
20	3871,42	1138,44	
Mean ± Std	2568,74±1207,52	1562,30±981,49	

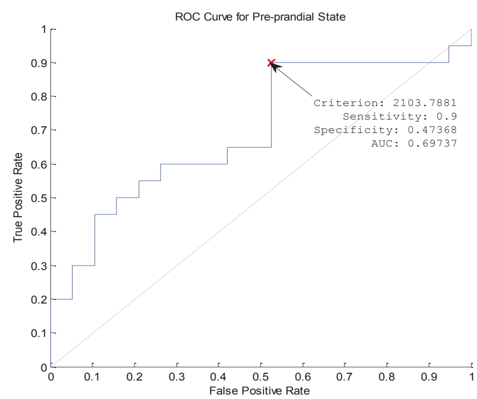

Figure 3. ROC curve for Pre-prandial stage

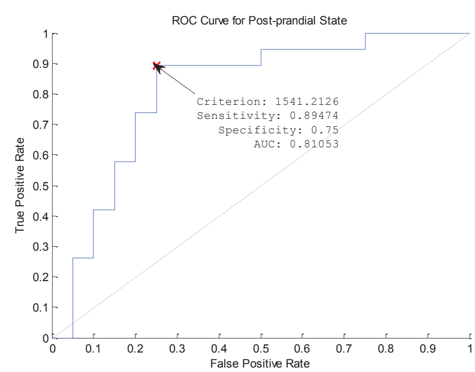

Figure 4. ROC curve for Post-prandial stage.

One possible reason of this can be dysrhythmia activities. There are two type of gastric dysrhythmia as bradygastria and tachygastria and gastroparesis patients have bradygastria and tachygastria too [3]. With bradygastria, the contractile efficiency of the stomach is reduced as a result of a decrease in the number of antral contractions. If an ectopic pacemaker, generates an oscillatory pattern at an abnormally high frequency then tachygastria occurs. Although retrograde depolarization may propagate with tachygastria;

retrograde motor activity rarely arises, as the electrical activity is insufficient amplitude to induce contraction. Thus, during tachygastria, the stomach is usually atonic. Such outcomes may appear as less variation on amplitude and frequency in EGG signals [15].

Another reason of the statistically significant difference between GP and CT may be due disappearance of ERA. ERA superimposed ECA and directly associated with contractions. It has two components as plateau and spikes and spikes cannot exist without plateau, while the plateau can exist without spikes [16]. If spikes do not occur, then the strength of the contractions is small and be under 0.25N. If there is an abnormality, the plateau and spikes or just spikes may not occur. In our hypothesis: this situation may affect the amplitude and frequency variations of EGG thus line length of GP group smaller than control. Of course to prove the hypothesis mucosal or serosal recording of GAE should done. However, these methods are invasive. When ERA is present it is closer to a random signal and its appearance is not synchronous in different section of stomach for healthy subjects [16 - 18]. Asynchronous and disappearance of ERA during stomach contraction may lead to an increase on the amplitude and frequency variations of gastric activity and so EGG.

Although, radioscintigraphy may be helpful in detection of delayed gastric emptying but it cannot provide information about the etiology and also it is very expensive. The reasons of delayed gastric emptying in GP patients can be gastric hypomotility and non-coordinated gastric contractions, which occur due to irregular ECA and also insufficient appearance of spikes in postprandial stage. These kinds of factors can be evaluated with GAE. And GAE can evaluate with EGG as a non-invasive manner. Therefore, EGG is an important tool to find a non-invasive, simple and cheap diagnosis and follow-up test after treatment for delayed gastric emptying in GP patients.

The studies have shown that the line length value of the EGG is a potential feature for discriminate the healthy subjects (CT) from diabetic gastroparesis (GP) patients also shown that the line length is capable to reflect the ERA effect on EGG. As a future work a computer-aided diagnosis system can design using line length with some other related features.

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