



Determining of Gastroparesis Disease from Electrogastrogram Signals Using Cramer-Rao Lower Bound and Power Spectral Density

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Abstract: *Gastroparesis is a chronic disease of stomach mobility, defined as delay in the emptying of food from the stomach without mechanical obstruction. Various methods are used for the diagnosis of gastroparesis and scintigraphy method is accepted as the gold standard. In this study, Electrogastrogram (EGG) signals were obtained from gastroparesis patients and healthy volunteers using cutaneous electrodes. Unlike the methods used in the frequency analysis of EGG signals in the literature, parametric methods have been used in this study and the selection of the method to be used has not been determined intuitively, it has been determined by mathematical calculations. Cramer-Rao Lower Bound (CRLB) method has been used to determine which method should be used for obtaining Power Spectral Density (PSD). Using selected parameter estimation method, PSD functions were obtained. Several features were extracted from the PSD functions and they were utilized to differentiate patient and healthy groups. As a result, features that can classify EGG signals from gastroparesis patients and healthy subjects, have been obtained. Best electrode placement that can be used for this disease has been achieved successfully.*

Keywords: *Gastroparesis, Electrogastrogram, Cramer-Rao Lower Bound, Autoregressive Parameter, Power Spectral Density*

1. Introduction

Gastroparesis is a chronic disease of stomach mobility, defined as delay in the emptying of food from the stomach without mechanical obstruction. Scintigraphic imaging, endoscopy, gastric manometer, breath testing and wireless capsule methods are used for diagnosis. The widely used diagnostic method in the clinic is endoscopy and scintigraphy. Delayed gastric emptying, which confirms the suspicion of gastroparesis, is measured by gastric scintigraphy. Scintigraphic imaging is accepted as gold standard in diagnosing delayed gastric emptying. However, scintigraphy is an invasive method. The main disadvantage of this method is that radionuclide is given to the subjects to be diagnosed and they radiate radioactive substance for imaging by gamma camera. Also, scintigraphy is an expensive imaging method. These disadvantages lead to search for different diagnostic methods for diagnosis of gastroparesis. EGG is an non-invasive and easy-to-implement method but it isn't routinely implemented because its results couldn't be standardized. However, the interest in this area has increased recently [1-3].

The EGG is a measurement method that gives information about the electrical activity of stomach. The EGG is obtained using surface electrodes placed on the skin surface in the abdominal region. First studies about EGG were performed by Alvarez in 1922 [4]. EGG has become a more commonly used method in practice due to the fact that it is not harmful to the patient. However its clinical use is limited. EGG is used commonly in diagnosing stomach disease, in treatment, and in electro physical studies. Gastric Electrical Activity (GEA) consists of two activities: Electrical Control Activity (ECA) and Electrical Response Activity (ERA). The ECA potential is a slow wave, and the ERA potential is called spike potential. The ECA is an activity that always identifies the stomach contractions. The slow rate of change of this activity has caused the ECA activity to be called slow waves. The ERA, which occurs for a longer period than the ECA, provides information about contractions. The normal frequency of the stomach ECA has 0.03 Hz-0.07 Hz. frequency range and 2.4-3.7 cpm (cycle per minute). Arrhythmias that may occur in the stomach will cause changes in the frequency spectrum of the EGG signals. Frequency range of the EGG signal 0,0033 Hz-0,03 Hz. and 0.2-2.4 cpm range shows bradygastria, 0.07 Hz.-0.15 Hz. and 3,7-9,0 cpm range

shows tachygastric. Obtaining these dysrhythmias in the EGG analysis is believed that provide diagnostic benefits. Analysis of arrhythmias of the EGG is defined as a diagnostic method in patients suffering from impaired gastric motility, vomiting, nausea, bloating, early saturation and reflux [5].

Gastric cancer, reflux, gastritis, indigestion, stomach ulcers, epigastric burning, unexplained vomiting, gastroparesis (delayed gastric emptying) and stomach irritability are common in gastric diseases [6].

Electrogastrography isn't a widely used method for the diagnosis of gastroparesis, but provides detailed information on the pathogenesis of gastrointestinal disorders. JD Chen et al. determined that saturation EGG abnormalities may detect delayed gastric emptying and showed that gastric emptying was associated with the EGG [1-3].

In literature, the EGG signals are analyzed using methods such as Power Spectral Density (PSD), Wavelet Transform (WT), Discrete Wavelet Transform (DWT), Fourier Transform (FT), Short-time Fourier Transform (STFT) and Fast Fourier Transform (FFT). Studies generally aimed to obtain dysrhythmia. Often time-frequency or frequency analysis methods are used [7-9]. In these studies methods to obtain PSD functions were selected instinctively.

In this study, CRLB method has been used to determine which method should be used for obtaining PSD of EGG signals [10, 11]. The best parameter estimation method was chosen per CRLB method. PSD functions were obtained for patients and healthy subjects using EGG signals. For classification, features have been extracted from PSD functions. The classification success was measured by Receiver Operating Characteristic (ROC) curves.

2. Methodology

For electrode placement to obtain EGG signals, different points and leads were used in scientific studies because of there is no exact points considered as gold standard. This shows that there should be many studies that need to be done on the acquisition and analysis of EGG signals [10, 12].

2.1. Data Acquisition

Patients who were diagnosed with gastroparesis at Erciyes University Medical Faculty Hospital were included this study.

In this study, the EGG signals were obtained from volunteers for 30 minutes on an empty stomach and 30 minutes on a full stomach for a total of 1 hour duration. After the fasting record, 536 kcal cheese (or turkey) sandwiches and 200 ml fruit juice menu standardized by dietitian were given to volunteers and the postprandial measurements were obtained (menu including: 69.4% carbohydrate, 13.8% protein and 16.8% fat). The medications used by the patient were discontinued at least 3 days prior to the EGG procedure. The volunteers were asked to stop eating

and drinking 8 hours before recording. The EGG recordings were obtained with 2 separate channels from the Biopac MP-150 system using 6 electrodes. First channel was obtained from 1st and 4th region's electrodes; second channel was obtained from 2nd and 3rd region's electrodes as seen in Figure 1. The EGG records were obtained from 15 healthy volunteers and 9 gastroparesis patients using electrode placements that indicated in ref. (10). All calculations were performed for two channel EGG signals to determine best electrode placement.

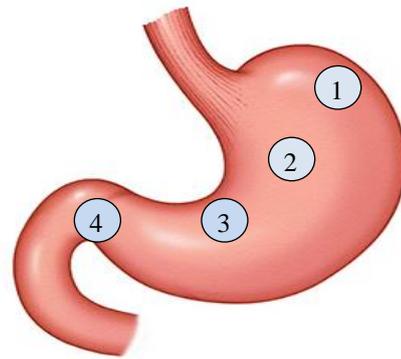


Figure 1. Electrode placements.

2.2. Gastric Emptying

Gastric emptying is the passage of food from pylorus to duodenum. It is provided by the peristaltic motion of the antrum region. Repeated peristaltic movements occur approximately three times cpm in healthy people. The food is divided into smaller pieces with the movement.

Peristaltic movement of the stomach is derived from depolarization of smooth muscle cells in plasma membranes. The oscillations in membrane potential are known as slow waves. Slow waves are generated by the muscles of the proximal corpus along the greater curvature (region of stomach). Greater curvature and region of stomach are shown in Figure 2 [7]. Studies show that slow waves are formed by pacemaker cells. Pacemaker cells are also named as interstitial cells of Cajal (ICCs). Slow waves of the stomach spread with small changes in the stomach. Slow waves cannot be reproduced when there is no ICCs connection, i.e. when the stomach muscles lose their ICCs. For this reason, the stomach cannot be controlled by slow waves, and peristaltic movement of stomach is impaired [13].

Impairment of the stomach peristaltic movements or changes in frequency may cause to disrupt stomach work or delay normal gastric emptying. The rate of gastric emptying varies based on the nervous and hormonal effects of both the stomach and duodenum. Increasing the nutrient volume at the stomach also increases the emptying rate of the stomach. The stomach is usually emptied four hours after eating. The emptying of liquids is faster than solid food. Longer or faster stomach emptying time causes several stomach diseases [14, 15].

Horowitz et al. indicated that solid matters left stomach after the liquids with a delay of 58% and 30% for type 1 and type 2 diabetics [15].

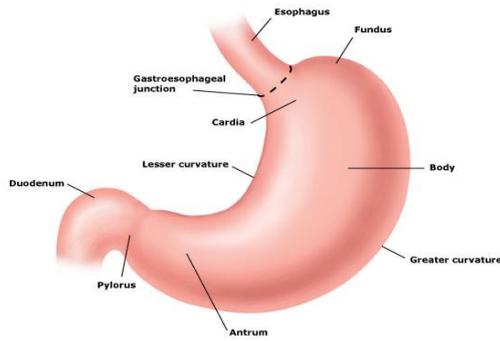


Figure 2. Regions of stomach [16].

Abnormalities in electrical activity of the stomach are called dysrhythmias. There are two types of dysrhythmia, tachygastric and bradygastric. Tachygastric is an increase in the frequency of normal electrical activity of the stomach (3 cpm). Bradygastric is a decrease in the frequency of the slow wave [1-3].

2.3. Gastroparesis

Gastroparesis, which means stomach paralysis, is a gastrointestinal disease caused by diminished or stopped stomach movements. Disease has symptom of delayed gastric emptying without any mechanical obstruction at the out of the stomach. Symptoms of gastroparesis include early feeling of fullness, nausea, vomiting, swelling of the abdomen, epigastric pain and weight loss. These symptoms can vary depending on the person. Different symptoms may not be specific for gastroparesis and symptoms may indicate other diseases. There isn't always an objective relation to the degree of gastric emptying due to the diversity of symptoms. Gastroparesis can occur due to diabetes, neurological, drug utilization or unexplained events. Diabetes is seen in about one-third of patients who are diagnosed with gastroparesis. One of the major complications of diabetes is diabetic gastroparesis [17,18].

Various methods are used for the diagnosis of gastroparesis. Endoscopy, gastric scintigraphy, gastric manometry, EGG, breath test, ultrasonography and intra-gastric imaging with wireless capsule are used for diagnosis. These methods are used to determine delayed gastric emptying [18]. Treatment of gastroparesis is performed with blood sugar control (for diabetic patients), diet, drug therapy, antiemetic therapy, endoscopic therapy with botulinum injection, gastric electrical stimulation and surgical approach [19].

The use of many methods in diagnosis and treatment of gastroparesis and the lack of definite diagnosis have increased gastroparesis as a field of study.

Recently, the gold standard of diagnosis is accepted as gastric scintigraphy. In this method, radioisotope food is given to the subjects to be imaged and the constellation of stomach is examined using gamma camera. Two hours after giving radionuclide, if half of

the food is still in the stomach, it is diagnosed as gastroparesis. The duration of the scintigraphy is important and should be long (e.g. 1, 2, or 4 hours). Also, expensive hardware is required for scintigraphy. When these disadvantages are considered, there is a need for a cheap and harmless method of diagnosis of gastroparesis [18,19]. Therefore, in this study EGG is used for diagnosis of gastroparesis.

2.4. Cramer Rao Lower Bound (CRLB)

CRLB is a general method used in statistical signal processing. It is accepted as a statistical method due to the use of probability density function for estimation. CRLB is used to determine the location of the target in radar systems [20], in submarine systems [21], in fingerprinting [22], in Doppler systems [23], and in determination of electrical dipole in EEG / MEG systems [24]. When studies are examined, the CRLB method is mostly used in areas such as target location, radar, submarine, navigation, communication systems, frequency estimation, interval estimation, Autoregressive (AR) parameter estimation and parameter estimation.

Parameter estimation of the system or model is important in analyses of the time series. Different methods are used to examine the accuracy of the estimated parameter. The method used for parameter estimation needs to have the lowest variance to make the closest estimate to the real value. Then, the method is considered to be the best estimation method. The variance bound, called Cramer-rao bound, is determined to estimate performance of the method. The estimate must be unbiased and have low variance so that the estimating process can be performed correctly. θ is parameter vector to be estimated, $\hat{\theta}$ estimated parameter vector, the variance of the estimate is calculated as in Eq. 1 [25].

$$\text{var}(\hat{\theta}) = E\left[\left(\hat{\theta} - E(\hat{\theta})\right)\left(\hat{\theta} - E(\hat{\theta})\right)^T\right] \quad (1)$$

In this equation $E[\cdot]$ is the expected value operator. The optimal estimate is determined by the mean value approach. If the variance is close to zero, the estimate is more accurate [25]. Bias is calculated by the equation $b(\hat{\theta}) = \theta - E(\hat{\theta})$. The bias gives measure of average deviation from actual value. If the estimation is unbiased, it is successful. It must be $E(\hat{\theta}) = \theta$ for unbiased condition. In the CRLB method, the probability density function is used for estimation. The probability density function including the unknown parameter is called *likelihood function* and is shown as $p(x;\theta)$. $\theta = [\theta_1, \theta_2, \theta_3, \dots, \theta_r]^T$ is the parameter vector to be estimated. In this method, first the natural logarithm of the likelihood function is calculated ($\ln p(x;\theta)$). Cramer- Rao lower bound is examined as follows [25]:

$$\text{var}(\hat{\theta}_i) \geq \left[I^{-1}(\theta) \right]_{ii} \quad (2)$$

Given $[I(\theta)]$ in Eq. 2 is fisher information matrix. This matrix is calculated by the equation as in Eq. 3 [25].

$$[I(\theta)]_{ij} = -E \left[\frac{\partial^2 \ln p(x; \theta)}{\partial \theta_i \partial \theta_j} \right] \quad i=1,2,\dots,p \quad ve \quad j=1,2,\dots,p \quad (3)$$

As can be seen from the above equation, the CRLB calculation is performed by taking the inverse of the Fisher information matrix. The Fisher matrix is obtained by computing the expected value of the derivative of the probability density function [25].

2.5. AR Parameter Estimation with CRLB

Kay obtained the Cramer Rao lower bound for AR parameters using the Power Spectral Density (PSD) of the AR model. The PSD of constituted by the estimated parameters for the {x [0], x [1],..., x [N-1]} data set is as follows [25]:

$$\hat{P}_{xx}(f) = \frac{\hat{\sigma}_u^2}{\left| 1 + \sum_{m=1}^p \hat{a}[m]e^{-j2\pi f m} \right|^2} \quad (4)$$

$$P_{xx}(f; \theta) = \frac{\hat{\sigma}_u^2}{|A(f)|^2}$$

$\theta = [a[1], a[2], \dots, a[p], \sigma_u^2]^T$ are parameters to be estimated. According to CRLB method, first $\frac{\partial \ln P_{xx}(f; \theta)}{\partial a[k]}$ and $\frac{\partial \ln P_{xx}(f; \theta)}{\partial \sigma_u^2}$ derivatives are calculated. After calculation of the Fisher information matrix, the lower bound for the AR parameters and the noise variance is calculated as in Eq. 5 [25].

$$\text{var}(\hat{a}[k]) \geq \frac{\sigma_u^2}{N} [R_{xx}^{-1}]_{kk} \quad (5)$$

$$\text{var}(\sigma_u^2) \geq \frac{2\sigma_u^4}{N}$$

In Eq. 5 R_{xx} is $p \times p$ dimensional Teoplitz matrix with $[R_{xx}]_{ij} = r_{xx}[i - j]$ equation.

Several AR parameter estimation methods are used in this study. The CRLB variance lower limit values are obtained for the estimated parameters of patients and healthy subject's signals. The best parameter estimation method was chosen based on this value and PSD calculation was performed using this method.

2.6. Power Spectral Density: Covariance Method

In model-based PSD methods, primarily parameters estimation is done for $x[n]$ ($0 \leq n \leq N$) data, then spectrum is obtained with these parameters. In the studies, AR parameters are used as a feature for classification patient/healthy subjects, for modeling or noise elimination. There are studies that used AR parameters to differentiate normal and abnormal EGG signals. In this area, a study did by Lin et al. attracted

the attention. Lin et al. used Autoregressive Moving Average (ARMA) parameters for classifying EGG signals as normal or abnormal using neural networks [26].

AR models are all zero models. The PSD obtained for the AR (p) model shown in Eq.6 is also explained in Eq.7.

$$y(n) = - \sum_{k=1}^p a(k)y(n-k) + x(n) \quad (6)$$

$$P(f) = \frac{\sigma^2}{|A(f)|^2} \quad (7)$$

$$A(f) = 1 + a_1 e^{-j2\pi f} + \dots + a_p e^{-j2\pi f p}$$

Autocorrelation method is generally used in AR parameter estimation. The difference of the covariance method is that matrices in calculations aren't Teoplitz matrices. AR parameter calculation for covariance method is given in Eq. 8. In this equation r_x is autocorrelation function. The advantage of the covariance method is that it doesn't apply window to data for the autocorrelation calculation [27].

$$\begin{bmatrix} r_x(1,1) & r_x(2,1) & \dots & r_x(1,p) \\ \vdots & & & \vdots \\ r_x(p,1) & r_x(p,2) & \dots & r_x(p,p) \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_p \end{bmatrix} = - \begin{bmatrix} r_x(1,0) \\ \vdots \\ r_x(p,0) \end{bmatrix} \quad (8)$$

$$r_x(k,l) = \sum_{n=p}^N y(n-l)y^*(n-k)$$

Final Prediction Error (FPE), Akaike Information Criterion (AIC) and Minimizes the Description Length (MDL) methods are used for choice of AR model degree. But in our study we defined model degree according to classification success and CRLB method.

In this study model parameters were used for 4th, 5th and 6th degrees. With these three degrees, features from the PSD function were obtained. Maximum area under the ROC defined highest classification success.

2.7. ROC Curve

The ROC curve is a method aimed at patient/healthy separation. This method is frequently used in medicine. The area under the ROC curve determines the accuracy of patient and healthy discrimination. If this area is 1, then perfect separation is provided. As seen in Figure 3, area is 0.5, interpreted as a worthless test [28].

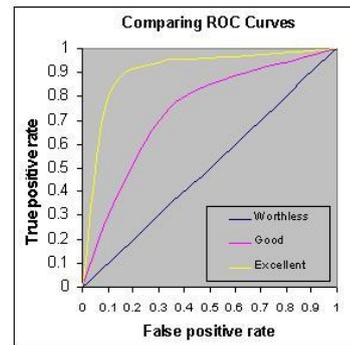


Figure 3. ROC curves according to performance assessment [28].

3. Results

In this study, 4th, 5th and 6th AR parameters were calculated from EGG signals of healthy individuals and patients by using Covariance, Burg, Yule-walker, Least Squares and Modified Covariance methods. To compare the methods, the CRLB variance value of these parameters was obtained. The method with the lowest variance value and the highest value method were selected and AR parameters were estimated by these two methods in all signals. CRLB values for averages of the 4th order AR parameters are shown in Table 1 and Table 2.

When Table 1 and Table 2 are examined, it is seen that covariance method gives the lowest value and Yule-Walker method gives the highest value. For this reason, AR parameters and CRLB were calculated by using covariance and Yule-walker method on EGG signals of all patients and healthy individuals.

Table 1. CRLB values for various analysis methods

Data	Method	CRLB value
Patient on empty stomach	Burg	0.937500181 E-06
	Covariance	0.937500144 E-06
	Modified Covariance	0.937500181 E-06
	Yule-Walker	0.937500229 E-06
	Least-Square	0.937500144 E-06
Healthy on empty stomach	Burg	0.937500195 E-06
	Covariance	0.9375001909 E-06
	Modified Covariance	0.9375001909 E-06
	Yule-Walker	0.937500259 E-06
	Least-Square	0.937500191 E-06

Table 2. CRLB values for various analysis methods

Data	Method	CRLB value
Patient on full stomach	Burg	0.937500154 E-06
	Covariance	0.93750015 E-06
	Modified Covariance	0.937500154 E-06
	Yule-Walker	0.937500194 E-06
	Least-Square	0.93750015 E-06
Healthy on full stomach	Burg	0.937500126 E-06
	Covariance	0.937500128 E-06
	Modified Covariance	0.937500128 E-06
	Yule-Walker	0.937500131 E-06
	Least-Square	0.937500128 E-06

4th, 5th and 6th degrees of AR parameters were estimated by covariance and Yule-walker methods for the EGG signals of patients and healthy people for fasting and satiety stages (for both channels). In Table 3, the mean and standard deviation of 4th degree AR parameters calculated by Covariance and Yule-Walker method were given for first channel data of patients at fasting state.

Table 3. AR parameter estimation

Method	a1	a2	a3	a4
Cov.	-1.41 ± 0.23	0.29 ± 0.2	0.014 ± 0.01	0.1 ± 0.11
Yule-Walker	-1.29 ± 0.16	0.15 ± 0.1	0.017 ± 0.01	0.11 ± 0.11

As in Table 3, the AR parameters were calculated using two methods for three degrees. This method is applied to all signals and the average of the parameters is examined. In other words, the a1 parameter was averaged for 9 patients and the Cramer-Rao lower bound was calculated. Finally, the averages of the CRLB values for the separately calculated parameters a1, a2, a3, a4 were obtained. For instance, Table 4 gives the CRLB values for the first channel of EGG signals obtained by patients.

Table 4. CRLB values of first channel in patients

AR Parameter Estimation Method	4 th degree	5 th degree	6 th degree
Covariance	5.25E-07	6.60E-07	7.53E-07
Yule-Walker	6.32E-06	1.09E-05	1.10E-05

Table 5. CRLB values of second channel in patients

AR Parameter Estimation Method	4 th degree	5 th degree	6 th degree
Covariance	1.36E-07	3.37E-07	4.72E-07
Yule-Walker	5.84E-07	6.93E-07	7.62E-07

Table 6. CRLB values of first channel in healthy people

AR Parameter Estimation Method	4 th degree	5 th degree	6 th degree
Covariance	5.95E-07	7.12E-07	7.93E-07
Yule-Walker	6.85E-07	7.77E-07	8.39E-07

Table 7. CRLB values of second channel in healthy people

AR Parameter Estimation Method	4 th degree	5 th degree	6 th degree
Covariance	5.57E-07	6.77E-07	7.60E-07
Yule-Walker	7.13E-07	7.98E-07	8.55E-07

Table 4-7 shows that the CRLB value is lower in the covariance method. From this result, it was concluded that this method will be more successful to obtain PSD. When the CRLB values for three different degrees were examined, it was seen that the AR parameters at the 4th degree were lower in both methods. For this reason, it shows that obtaining the PSD functions from the 4th degree with the covariance method will give more accurate results. The PSD obtained from a patient's EGG signal is shown in Figure 4.

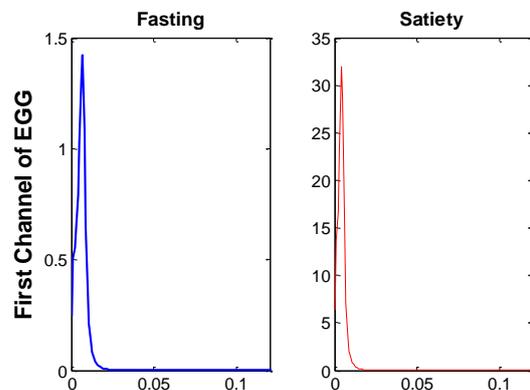


Figure 4. Graphical representation of PSD for a patient

Identification of feature vectors is very important for classification studies. Because attributes that are well chosen and distinctive for the signal enhance the success in classification. For this reason, it is necessary to pay attention to the analysis of the signal and to select those with high separation efficiency from the obtained characteristics. In order to be used in classification, area calculations as features have been carried out numerically on the PSD graphics as shown in Figure 5.

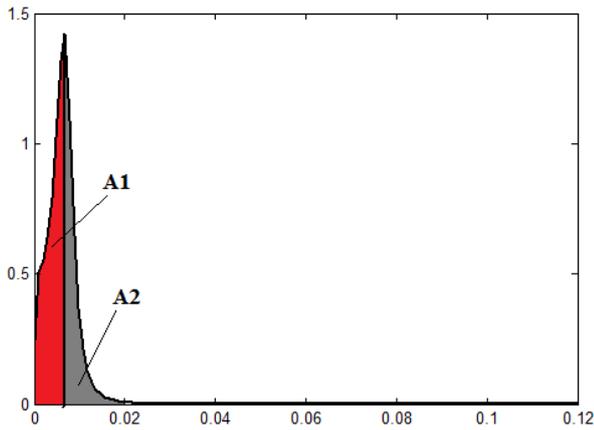


Figure 5. Area account on graphic obtained from PSD function

This field is calculated to the point where the chart is maximized (A1 field is expressed in red color) and after maximum (A2 field is expressed in gray color). Four features extracted from PSD functions, these features:

- A1 area value
- A2 area value
- The ratio of A1 area to total area
- The ratio of A1 area to A2 area

These values separately calculated for first-channel and second channel EGG obtained from patients and health subjects. According to area under the ROC curves results, there is no successful outcome for the first channel in the fasting and satiety stage between the patient and healthy groups. This result shows that EGG signals belonging to patients and healthy people are similar for the first channel in terms of frequency characteristic.

Table 8. Area values under the ROC curve

Second Channel	A1 Area	A2 Area	A1/Total	A1/A2
Hungry	0,919	0,978	0,978	0,881
Satiate	0,956	0,844	0,844	0,904

According to the results obtained from second channel EGG signals in Table 8, A1, 91%, A2 area 97.8%, A1/Total area 97.8% and A1/ A2 88.1% can differentiate between patient and healthy group. In addition, in the satiety stage, the A1 area 95.6%, the A2 area 84.4%, A1/Total value 84.4% and A1/A2

90.4% classify the patient and healthy group successfully.

4. Conclusions

When the frequency analysis studies with EGG signals are examined, it is seen that FT, FFT, STFT and Welch method are mostly used. In this study, parametric methods such as Burg, Covariance, Modified Covariance, Least Squares and Yule-Walker were used instead of the nonparametric methods in the literature. The most successful method for estimating AR parameters was decided by the CRLB method. The covariance method gives a lower variance value in AR parameter estimation results obtained from EGG signals from healthy subjects and patients. For this reason, it was decided to use the covariance method for the calculation of the PSD values. The 4th, 5th and 6th degree PSD functions were obtained from the patient and the healthy EGG signals using the covariance method determined by the CRLB method. When results were evaluated by ROC curve, the success rate of 4th degree PSD was 97%, while the success rate of 5th degree PSD was 85% and the success rate of 6th degree PSD was 92%. Thus, for the AR parameters, the choice of 4th degree is more accurate. This proves the validity of the CRLB method. The model degree is determined as the 4th degree giving the smallest CRLB value. Thus, the features that are obtained from PSD functions to identify patients and healthy groups could become more distinctive.

The areas shown in Figure 5 are calculated from the PSD functions generated by the covariance method. The features obtained from first channel data of EGG signals for fasting and satiety stages were not sufficient to differentiate the patient and the healthy group. All the features calculated from the PSD functions for the second channel signals, which were obtained from the patient and healthy people at fasting and satiety stage, differentiate the groups according to the ROC curve results.

When the A1 area is examined for patients and healthy subjects in the stage of fasting, this area value is higher for patients. The high value of this area indicates bradygastria in patients at fasting state. Thus, it was determined that bradygastria occurred for the patients while healthy people were within the normal frequency range according to PSD functions.

As shown under the heading "Data Acquisition" in the second part, the second channel signals correspond to the point at which the gastric pacemaker, i.e., the stomach movement is initiated and advanced. It is shown that according to the second channel data, there are differences in the electrical activity of the stomach between the healthy subjects and patients from EGG signal.

Based on the results of the frequency analysis, it was concluded that the bradygastria were shown for the patients as seen PSD functions, and that the gastric electrical activity was slowed down. In this study, electrode placement and features were obtained which can differentiate EGG signals obtained from healthy and patient subjects. As a result, the proposed methods have obtained the features that will reveal the differences between two groups. It has been concluded that for patients with gastroparesis disease, signals obtained from second channel

(2-3 electrode placement) are more successful to classify patients/healthy groups. Obtained results show that, using CRLB and PSD methods can help diagnose gastroparesis and contribute to the literature.

5. Acknowledgment

In this study, signals are obtained from volunteers by approval of ethics committee of Erciyes University Clinical Research Ethics Committee (approval numbered 2015/115).

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