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ADAPTIVE SPECTRAL ANALYSIS OF GASTRIC MYOELECTRICAL ACTIVITY IN PATIENTS WITH RENAL FAILURE

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ABSTRACT:

Abnormalities in the gastric electrical activity (GEA) and cutaneous Electrogastragram (EGG) have been studied in variety of clinical conditions related to digestive system and its motility. Unfortunately, the impact of renal failure on GEA remains in question especially with patients performing regular Haemodialysis. The aim of this study is to determine whether EGG would be changed in patients with renal failure even after Haemodialysis to become as healthy control.

An experiment was conducted on two groups: The first group contained (11) healthy volunteers with average age (23) years, free from any diseases related to digestive system and renal failure. The second group was selected from patients suffering from renal failure and performing regular Haemodialysis twice a week (10 patients) with average age of (27.5) years. EGG was measured non-invasively from both groups for 20 minutes and digitized with sampling frequency 2 Hz before pre-processing stage. In the preprocessing stage, the EGG signal becomes noisily suppressed using an adaptive enhancement technique. Based on parametric modeling, and the nonstationarity of EGG, the instantaneous EGG signal is modeled by adaptive Autoregressive (AR) model. The power spectrum of EGG signal can be calculated from those time-varying parameters, which are updated with on-line EGG samples. Therefore, the instantaneous frequency of EGG signal would be tracked.

This approach has the ability to provide how far the fluctuations with renal failure from normal will be. The accuracy of classification with adaptive AR coefficients using RLS algorithm shows higher percentage for discrimination than other techniques as LMS. The percentage of classifying patients with renal failure before Haemodialysis from normal persons reaches 98.75%. It is expected that the GEA of the digestive system would become normal after Haemodialysis, but evident differences in EGG power spectrum were found, and patients after Haemodialysis were discriminated easily from normal with percentage 100% using scatter diagram. Finally, these results showed that GEA did not reach the control level even after Haemodialysis (5hours/session).

KEYWORDS:

Electrogastragram (EGG), Adaptive AR, Renal Failure. Haemodialysis

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I. INTRODUCTION:

The physiological function of the stomach is a complex combination of electrical and mechanical activities to perform digestion. The gastric electrical activity and cutaneous Electrogastrogram (EGG) of the stomach are studied to characterize the clinical state (Normal or Abnormal) of stomach related to its motility during digestion [1,2]. Measurement and analysis of EGG signal become very important from clinical point of view to evaluate its motility. The following question stands and needs to be answered. What is the impact of renal failure on stomach activity? Specifically, is it possible to detect the reflection of renal failure on EGG? It is well known that the main function of kidneys is to form urine out of blood plasma. This process consists of two phases: i) the removal of waste products from blood plasma; and ii) the regulation of the composition of blood plasma. The signs of renal malfunction are known as uremia, meaning urine in the blood. When urinary contents reach high concentrations in blood and hypertension results and all body parts and their physiology are influenced [3]. To compensate the renal failure, Haemodialysis is performed for blood purification. More removal can be achieved by increasing the duration of the procedure, but long duration causes blood fractionation. Therefore, most of Haemodialysis sessions take from 4-6 Hours, and blood would not be completely purified [4]. On the other hand, the signal processing techniques can provide us with tools to extract the main features from measured EGG to be used for diagnosis [5]. The Adaptive Autoregressive (AAR) approach [6] as one of these tools is used here as it provides an easy and fast way for signal representation even under noisy conditions. Since the measured signals are nondeterministic [7], this technique would be used to formulate a parametric representation of the measured EGG time series. The estimated coefficients of AAR would be used as features to characterize stomach states for discrimination and further analysis.

II. FORMULATION OF THE PROBLEM:

The digestive system is assumed to be stimulated with inaccessible input and EGG as its output. It is required to construct a mathematical model such that it expresses the functional relationship between system input and its output. Starting with postulating certain mathematical structure of the proposed system, the model output will be calculated in response to its input (the same as system input). Following to that, the deviation $\{e(k) \ k=1,2, \dots \ N\}$ between model output and system noisy measured output will be calculated. If the selected performance index (J) that depends on minimum mean squared error (MSE) between system and model output becomes out of the prescribed level, the model structure will be changed as shown in Fig.1. In our application, the performance index (J) is considered to be MSE of spectral deviation between the spectrum of measured EGG and estimated spectrum by AAR model. This loop will continue until minimum (J) will be achieved.

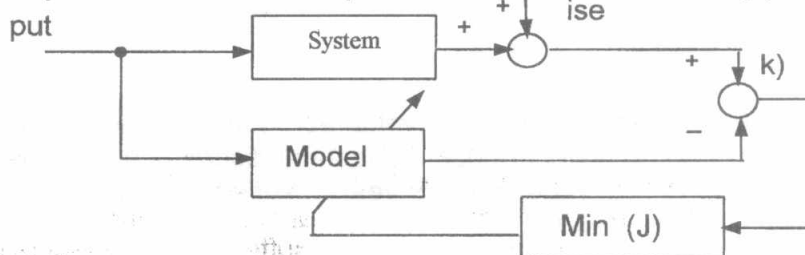


Fig.1. Block diagram of system-model interaction

The proposed model can predict the value of the signal as follows:

$$\hat{y}(n) = - \sum_{m=1}^M a_m(n) \cdot y(n-m) + v(n)$$

Where:

$v(n)$:is assumed to be White Gaussian sequences with zero mean and variance σ^2 .

$\hat{y}(n)$:is the estimated EGG signal.

$a_m(n)$:the mth coefficient of the AR Model at instant n.

M :AAR model order.

Because this model has an all-pole structure, the instantaneous poles should be within unit circle of Z-plane to yield stability. The estimated model order (M) will be changed such that the selected performance index (J) is achieved. The steps of the algorithm are illustrated in Table 1.

Table 1. Algorithm of the RLS adaptive AR Coefficients Estimation

<p>Remove DC level from input signal $IR(0) = 0.01 \cdot I, \lambda = N/(N+1)$ For n=1 to N N.... Number of samples in the measured signal Calculate the Kalman gain vector: $\underline{g}(n) = \frac{IR(n-1) \underline{y}(n-1)}{\lambda + \underline{y}(n-1)^T IR(n-1) \underline{y}(n-1)}$ Calculate: $err(n) = y(n) + \underline{a}(n-1)^T \underline{y}(n-1)$ Calculate the prediction coefficient vector: $\underline{a}(n) = \underline{a}(n-1) - \underline{g}(n) err(n)$ Calculate the inverse matrix: $IR(n) = \frac{1}{\lambda} \left[IR(n-1) - \frac{IR(n-1) \underline{y}(n-1) \underline{y}(n-1)^T IR(n-1)}{\lambda + \underline{y}(n-1)^T IR(n-1) \underline{y}(n-1)} \right]$ Calculate the predicted signal: $\hat{y}(n) = - \underline{a}(n)^T \underline{y}(n-1)$ Calculate the estimation error: $e(n) = y(n) - \hat{y}(n)$ End-For</p>
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III. MATERIAL AND METHOD:

The study was performed on 11 healthy volunteers (all male, age = 21-25 years, average = 23 years) with no history of gastrointestinal diseases and 10 patients (all male, age = 20-35 years, average = 27.5 years) suffering from renal failure and perform Haemodialysis twice a week.

The experiment was conducted on two phases:

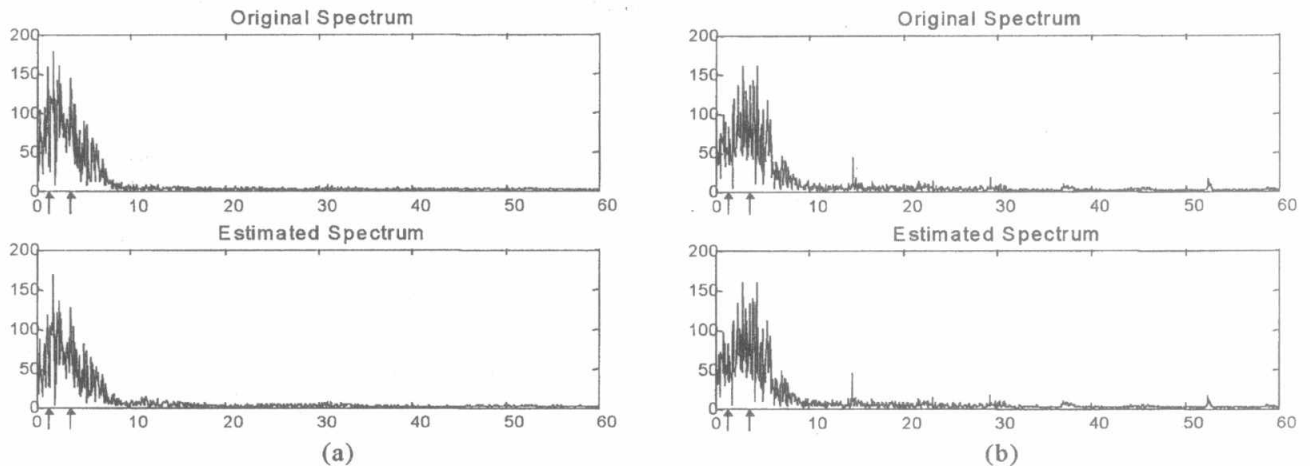
- i) In the first phase, all healthy subjects fasted for 12 hours prior to the measurements of EGG. Also, all patients perform EGG measurements before Haemodialysis.
- ii) The second phase deals with healthy persons after getting a special solid meal and patients after Haemodialysis.

During both phases, the longitudinal axis of the distal stomach was determined by ultrasonography and the recording sites were cleaned to achieve better condition. Biopotential skin electrodes were placed on the predetermined abdominal sites. EGG signal was acquired with a data acquisition system type DAC-12 equipped with 8-bit A/D. The subjects were lying in a supine position and instructed to minimize body movements and not to talk during the study. The recordings were acquired during 20 minutes using the DAC-12 with sampling rate of 2 Hz. A 486DX2-66 PC is used in the acquisition process. The digitized EGG data was stored in files with ASCII format for further processing.

IV. RESULTS:

The EGG signals were preprocessed to remove the interfered noise using adaptive line enhancer (More details about it are available in [8]).

Using Recursive Least Squares (RLS) algorithm, the AAR coefficients will be estimated. It is found that the best order of AAR is $M=5$. Increasing AR order will not show significant decrease of Mean Squared Error (MSE) of spectral deviation. Figure 2 shows a comparison between measured (original) and estimated spectrum for individual groups [Fasten, Digestion Fig.2 (a, b), Before and After Haemodialysis Fig.2 (c, d)]. Where arrows point at 2 and 4 cycle / minute [cpm], the normal range of EGG spectrum.



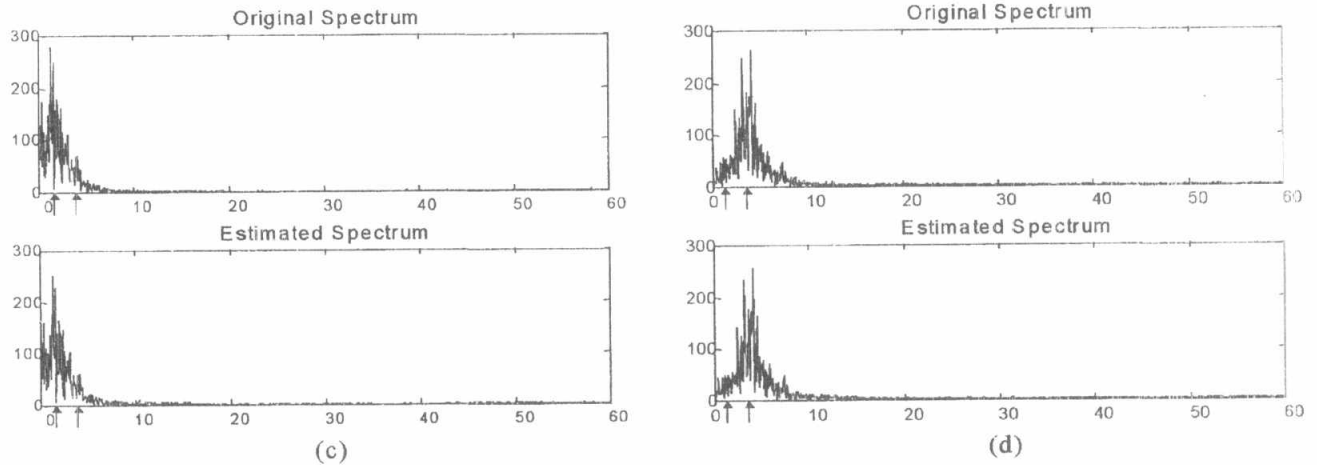


Fig.2. Original and Estimated spectra for EGG Signals:
 (a) Fasten, (b) Digestion, (c) Before, and (d) After Haemodialysis

This Figure shows a comparison between the spectrum of the original and estimated EGG signals for Fasten, Digestion, Before and After Haemodialysis respectively. Considering the maximum peak of the measured spectrum, the adaptive AR succeeded to estimate it with acceptable accuracy (MSE) as depicted in Table 2.

Table 2. MSE between the maximum peak of original and estimated signals

State	Max. Peak	MSE
Fasten	2.11	0.00011
Digestion	2.93	0.00012
Before Haemodialysis	1.289	0.00023
After Haemodialysis	4.16	0.00034

The time variations of AR coefficients are illustrated in Fig.3.

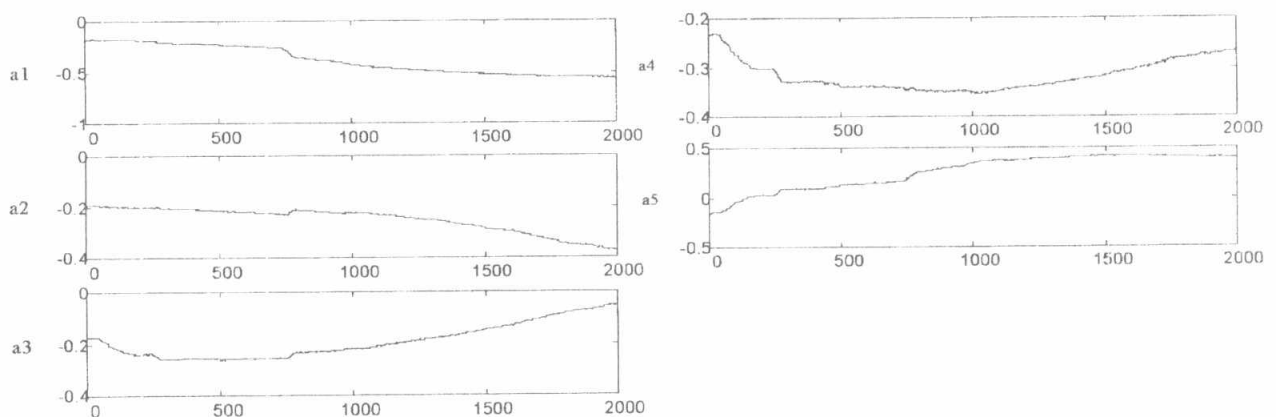


Fig.3. Time variation of adaptive AR coefficients

The mean values of the AR coefficients variation are illustrated in Table 3.

Table 3. Mean values of AR coefficients

Coefficients	Mean Value	Standard Deviation
a_1	-0.3858	0.1427
a_2	-0.2522	0.0516
a_3	-0.1913	0.0625
a_4	-0.3186	0.0300
a_5	0.2562	0.1653

To evaluate the efficiency of AAR coefficients for discrimination, a scatter diagram of the resulting mean value of coefficients for Fasten and Digestion states is shown in Fig.4-a. It is clear that the 2 states can be identified with a straight line, with an accuracy of 93.75% for the Fasten EGG Signals, and 90.91% for the Digestion EGG Signals. Similarly, Fig.4-b shows a scatter diagram for patients with renal failure, the two states could be discriminated with an accuracy of 90 % for before Hemodialysis state, and 91.25% for after Haemodialysis state.

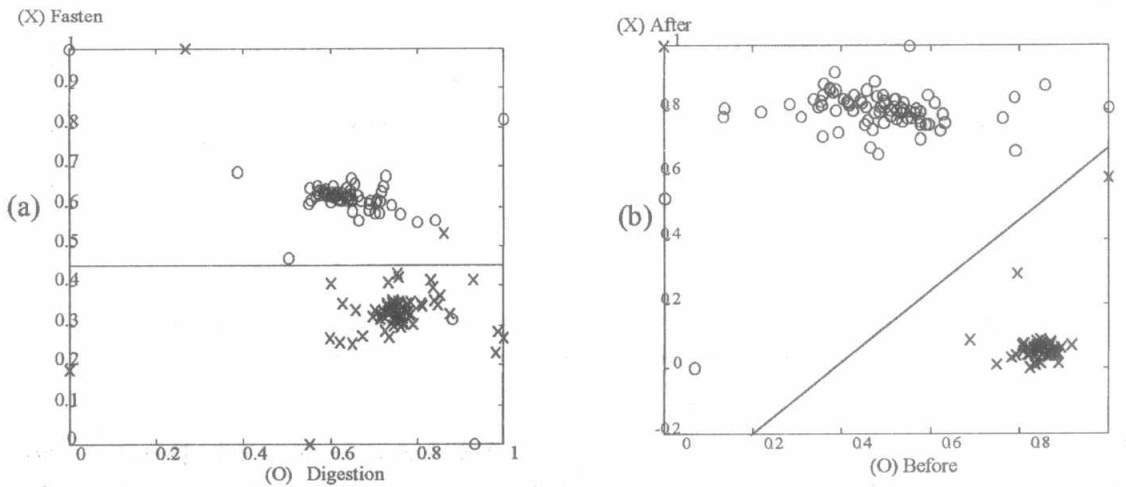


fig.4. Scatter Diagram for Discrimination between stomach states: (a) Fasten/Digestion, and (b) Before/After

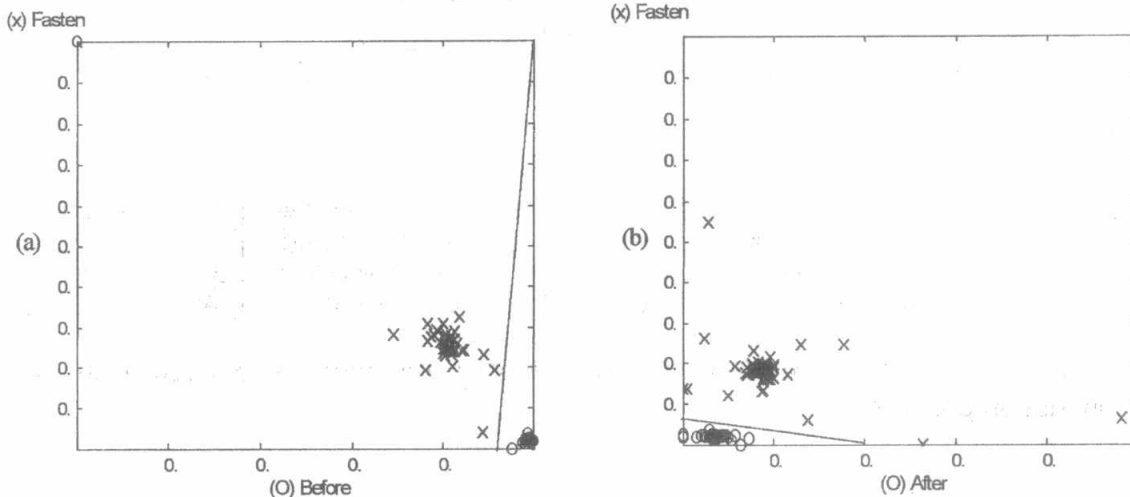


Fig.5. Scatter Diagram for Discrimination between stomach states: (a) Fasten/Before, and (b) Fasten/After

Also, AAR coefficients especially a_1 , show efficient discrimination between all possible combinations of both states of normal and patients. Figure 5 (a, b), illustrate the scatter diagram between Normal (Fasten state) and patients Before and After Haemodialysis the resultant accuracies are 98.75% for both Fasten and Before in case of Fasten Vs Before Haemodialysis, and 98.75% for Fasten, 100% for After in case of Fasten Vs After Haemodialysis.

Figure 6 (a, b), show the discrimination between Normal (Digestion state) and patients Before and After Haemodialysis with accuracy of 98.75% for Digestion and 100% for Before in case of Digestion Vs Before Haemodialysis, and 98.75% for both Digestion and After in case of Digestion Vs After Haemodialysis

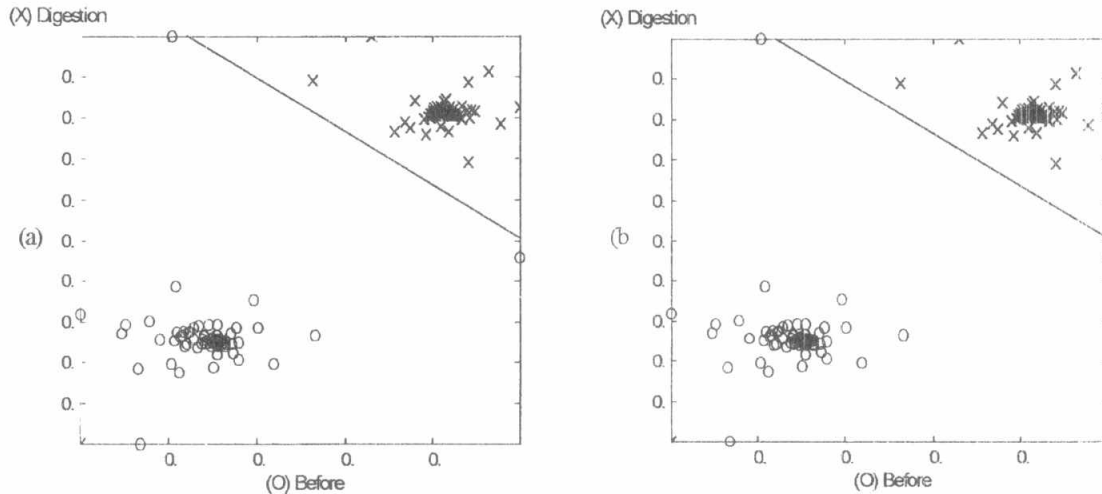


Fig.6. Scatter Diagram for Discrimination between stomach states: (a) Digestion/Before, and (b) Digestion/After

Comparing off-Line AR with AAR; a significant difference is available between mean values of AAR Coefficients and corresponding off-Line AR. This difference has remarkable influence on the percentages of discrimination, as shown in Table 4.

Table 4. Difference in accuracies of discrimination using off-Line AR and AAR Coefficients

Coefficients tomach tates	Adaptive AR		Off-Line AR	
	F/B	Fasten=98.75%	Before=98.75%	Fasten=90.25%
F/A	Fasten=98.75%	After=100%	Fasten=88.54%	After=91.25%
D/B	Digestion=98.75%	Before=100%	Digestion=89.1%	Before=92.25%
D/A	Digestion=98.75%	After=98.75%	Digestion=92.1%	After=97.75%

Table 4 depicts the difference and its influence on decreasing accuracies of discrimination process.

V. CONCLUSION:

The measured cutaneous EGG is a combination of GME activity and noise such as respiratory and motion artifacts. Adaptive Line enhancer in preprocessing stage is necessary for further processing. Due to the absence of a standard pattern of EGG (as in ECG) spectral analysis is preferred to differentiate abnormal from healthy control. The adaptive spectral analysis provides reliable information especially about the presence of peaks of EGG spectrum in and outside frequency range 2-4 [cpm]. Although patients with renal failure took solid meals during Haemodialysis similar to control groups, there is a significant change in EGG spectrum even after Haemodialysis. Using coefficients of adaptive AR model, it became easy to discriminate patients for healthy groups using scatter diagram with accuracy between $(95.5 \pm 3) \%$

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