



ORIGINAL PAPER

# Some early results related to electrical impedance of normal and abnormal gastric tissue

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**Abstract** Gastric cancer is the fourth most common cancer and most patients with gastric cancer are being diagnosed in advanced stages of the disease so they do not gain any survival chance from conventional surgical, chemotherapeutic or radiotherapeutic methods. These are relatively high cost procedures in terms of both time and money. This study considers the introduction of a novel minimally invasive diagnostic technique which shows the relationship between histopathology and the electrical impedance spectrum in the human stomach. In this study, 4 electrode technique was used to differentiate tissues from each other using Tabriz Mark 1 electrical impedance system (30 different frequencies in the range of 2 kHz to 1 MHz). A total of 97 points from 45 patients were studied in terms of their biopsy reports matching to the electrical impedance measurements (*in vivo*). After impedance measurements and applying calibration factors, a non-parametric statistical technique, the Kruskal–Wallis test was used to evaluate the difference among the groups. According to the calculation of respective data using this spectroscopy system, the resistivity of the normal group was higher than that of the benign group, and the resistivity of these groups were higher than that of the malignant group at frequencies between 470 kHz and 1 MHz ( $P < 0.05$ ). In these frequencies, the impedivity of the dysplastic tissue was significantly lower than that of the other groups ( $P < 0.05$ ). Also, Cole equation fitting procedure was used to generate a scatter plot of the malignant and benign points: it shows in general, benign points had higher values of  $R$  than the malignant points. Therefore, electrical impedance spectroscopy can be a useful technique to characterize the stomach tissue.

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## Introduction

Gastric cancer is the fourth most common cancer and second leading cause of cancer related death in the world. According to a global estimation, more than 930,000 new cases of gastric cancer are being diagnosed each year and a minimum of 700,000 patients die from the disease [14]. Unfortunately, the symptoms of early gastric cancer are non-specific and rather vague [1,4]. Most patients with gastric cancer are being diagnosed in advanced stages of the disease and they do not have survival chance from conventional surgical, chemotherapeutic or radiotherapeutic methods. Therefore early cancer detection using an efficient surveillance program is a justified way to reduce gastric cancer mortality [13]. These methods of population screening for gastric cancer are being adopted in Japan, South Korea and a part of Taiwan [11]. Various investigations are currently available to help with the diagnosis of gastric cancer as follows: radiological (double-contrast barium) techniques, endoscopy and pathologic assessment, ultrasound scans, CT-Scan, Laparoscopy, and biological serologic tests for serum pepsinogen (PG I, PG II) [4]. Gastric pathology is usually investigated visually by endoscopy. Abnormal areas are usually observed but this can represent a number of conditions ranging from gastritis to adenocarcinoma. Biopsies must be taken from the suspected area in order to obtain diagnostic information. The selection of biopsy sites depends on simple visual inspection so it is effectively random. This is an invasive and relatively high cost procedure in terms of both time and money and is associated with discomfort for the patient and morbidity. It is important to emphasize that annual screening endoscopy and biopsy should be considered for patients who have been found to have atrophic gastritis, dysplasia and adenomatous polyps [1]. Although, the weakness of the above methods are lack of early detection of flat lesions within the stomach. However, the diagnostic accuracy of endoscopy and biopsy for primary upper gastrointestinal cancer is in the 95% range [4]. Thus, pathologic assessment remains the gold-standard for investigating these patients. In the light of this background, it is possible that electrical impedance spectroscopy may be appropriate for the early detection of flat lesions and assessing gastric pathology. The electrical impedance technique has the ability to characterize any electrical activities between pathologic areas as flat lesion. Thus, this technique can distinguish the pathologic areas from the normal tissue. However, the electrical impedance of normal and malignant regions of any tissue can be different [8].

Therefore, this paper considers the introduction of a novel minimally invasive diagnostic technique to separate pathologic tissue from normal tissue (as some early results related to electrical bio-impedance of normal and abnormal gastric tissue). One example is the relation between tissue structures and electrical flow in cervical neoplasia, to compare the impedance of normal and abnormal cervical tissues [3]. Another study investigated virtual biopsies in Barrett's oesophagus, using electrical impedance measurements [5]. The aim of their study was to show the possibility of differentiating two types of epithelium (squamous and columnar) in terms of their

electrical impedances. Another study has been proposed in which electrical impedance spectroscopy can detect bladder pathology, using low and high frequencies [6,7].

## Methods

A total of 97 points from 45 patients were randomly studied using their biopsy reports and the electrical impedance measurements (*in vivo*). Although, a total of 140 impedance data were recorded from 55 patients, only 97 data from 45 patients were used in this study because they fitted in Cole–Cole equation. The two positive and negative groups which were used to analysis the ROC are the following:

Group 1: benign or non malignant: chronic gastric area and intestinal metaplasia

Group 2: malignant: adenocarcinoma and dysplastic area  
Table 1 shows the number of cancerous and benign patients:

According to Table 1, 8 patients had gastric cancer which the impedance data were taken from their normal and pathologic tissues. Later, these were categorized due to their pathological results. The malignant group was patients with Adenocarcinoma (gastric cancer). Bio-impedance measurements were performed at 30 different frequencies in the frequency range of 2 KHz to 1 MHz using electrical impedance spectroscopy system (Tabriz Mark 1). The applied current to measure the transferred impedance in this study was 10  $\mu$ A peak-to-peak which was passing through two electrodes of a small sized probe. This system is a type of research instrument that has been used to characterize the gastric epithelium.

It was designed and constructed in the Electronic Engineering Department, University of Tabriz, Tabriz, Iran. The measured data was transferred to a laptop and picoscope (PC Oscilloscope) using measurement hardware. The resulting potential was measured using the other two electrodes to obtain the electrical impedance of the gastric tissue. The design, construction, development and mechanical assembly of a smaller size probe (2 mm diameter) including 4 gold electrodes to use 4-electrode technique in the gastric tissue were made carefully. The reason of the high importance is because injection of electrical current into living tissue, *in vivo* and measuring its bio-impedance need a very small sized probe. The size of the probe was 2 mm total in diameter and sufficient enough to insert into the endoscope (refer to Fig. 1c for details). However the maximum permitted diameter of probe had to be 2 mm in order to pass through the endoscope to measure the impedance of the inside of gastric tissue. In terms of tip designing, the circular shape of the tip, instead of the planar shape, made the

**Table 1** The number of patients and prepared biopsies from every type of tissue.

| Number of patients | Number of biopsies | Tissue type     |
|--------------------|--------------------|-----------------|
| 10                 | 22                 | Normal          |
| 8                  | 19                 | Adenocarcinoma  |
| 3                  | 7                  | Dysplastic area |
| 24                 | 51                 | Benign area     |

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