European Journal of Clinical Oncology 2024, Vol. 06, Issue 01, 001-003 Research Article

The Importance of Fourier-Transformed Infrared Spectroscopy (FT-IR) in the Diagnosis of Stomach Cancer

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Received date: 14-Dec, 2023, Manuscript No: ejco-23-113628; **Editor assigned:** 16-Dec-2023, PreQC No - ejco-23-113628 (PQ); **Reviewed:** 02-Jan-2024, QC No. ejco-23-113628 (Q); **Revised Date**: 11-Jan-2024, Manuscript No: ejco-23-113628 (R); **Published date:** 22-Feb-2024, DOI: 10.35248/clinical-oncology.23.6(1)003-006

Abstract

Fourier Transform Infrared Spectroscopy (FT-IR) is an essential analytical technique in diagnosing stomach cancer. FT-IR spectroscopy provides information about the molecular vibrations of a substance in the infrared region. This technique is vital in diagnosing and researching diseases such as cancer. The importance of FT-IR spectroscopy in diagnosing stomach cancer can be summarized as follows: Rapid and sensitive diagnosis: FT-IR spectroscopy provides rapid and sensitive diagnosis by analyzing cell samples obtained from biopsy material. This is of great importance in diagnosing cancer and determining the stage of the spread of the disease. Potential to be non-invasive: In some cases, FT-IR spectroscopy can be used as a non-invasive method. It can help diagnose the disease without harming the patient or requiring a biopsy. This can improve patient comfort and reduce the risks associated with invasive procedures. Differentiation between different conditions: FT-IR spectroscopy can help distinguish stomach cancer from other states with similar symptoms. This is important for correct diagnosis and appropriate treatment. Use in treatment and monitoring: FT-IR spectroscopy can also be used to evaluate the response of cancerous cells during treatment and to monitor treatment efficacy. Thus, it helps to optimise the treatment process and create the most suitable treatment plan for the patient. Understanding biological differences: Understanding the molecular differences between stomach cancer cells and normal cells helps us better understand the mechanisms of the disease. This contributes to the development of new treatment methods and the determination of the root causes of the disease. This study aims to show that Fourier Transform Infrared Spectroscopy (FTIR) can be an alternative to these imaging methods in diagnosing stomach cancer.

Keywords: FT-IR Vibration Spectroscopy • Stomach cancer • Diagnosis

Introduction

Stomach cancer is among the most critical cancer cases in various parts of the world, especially in East Asian countries. If we compare it with other types of cancer, it ranks 5th in cancer cases worldwide. However, it ranks 4th in the death rankings [1]. Stomach cancer accounts for approximately 8% of all cancers, with approximately 989,600 new cases and 738,000 deaths annually worldwide. At this rate, it is one of the most common cancer types worldwide [2]. If the incidence rate is compared to women, it has been determined that this rate is higher in men in developing countries [3]. When we look at this rate in Turkey, it is ranked 5th as the most common type of cancer in men and 6th in women [4].

While the mortality rate was 8.86 per 100,000 people in 1990, it decreased to 5.24 in 2005 [5]. Compared to the cancer-related death rate per hundred thousand people, Japan takes the first place with 78/100000. In the USA, this rate is 13/100000, in the UK, it is 22/100000, and in Turkey, it is 11.9/100000 [2]. In recent years, there have been significant advances in stomach cancer incidence and diagnostic methods worldwide. Thanks to these developments, a significant decrease in death rates due to stomach cancer worldwide has been observed due to advances in surgical techniques and medical oncology treatment methods.

Many studies have investigated factors thought to be effective on prognosis in stomach cancer. Gender, age, blood group, tumor stage, tumor markers (CEA, Ca 19-9), tumor localization and diameter, hemoglobin and albumin level, histological differentiation degree, macroscopic type, body mass index, number of metastatic lymph nodes, preoperative surgery type, lymphatic dissection, chemotherapy modalities, radiotherapy, and prognostic factors in stomach cancer patients have been investigated in many different studies [6].

In treating stomach cancer, one or more of surgery, radiotherapy and chemotherapy can be used together. Surgery is a potentially curative treatment method for stomach cancer. The disease stage is the most important parameter in the treatment approach [7]. Many imaging methods are available for the diagnosis of stomach cancer, such as ultrasonography, endoscopy, Computed Tomography (CT), Magnetic Resonance (MR) and endoscopic ultrasonography. Among these imaging methods, endoscopy is among the most important gold standards [8–10].

Diagnostic methods of Stomach Cancer

A thorax, abdomen and pelvic CT scan may usually be sufficient to diagnose stomach cancer. In addition to diagnosing stomach cancer, the primary purpose of CT is to evaluate metastatic disease. To fully evaluate some lesions seen on CT, FluoroDeoxyGlucose (FDG)-Positron Emission Tomography (PET)/CT is required [11]. Endoscopic ultrasonography is recommended for the evaluation of stomach cancer patients without metastases due to better evaluation of tumour borders and location, evaluation of lymph nodes and surrounding organ involvement [12]. Endoscopic ultrasonography plays a very important role in neoadjuvant treatment decisions [12].

FTIR spectroscopy is a unique technique that shows the absorption bands of molecules in biological systems such as lipids, proteins, carbohydrates, and nucleic acid (RNA, DNA) in a single spectrum, allowing these molecules to be monitored simultaneously and without any labelling technique. This technique has been widely used in diagnosing and characterizing diseases in recent years, along with developments in spectral analysis and chemo-metric methods based on spectral changes. For this reason, we aim to show that FTIR spectroscopy can be used as a cheap, fast and successful cancer diagnosis method from body fluids such as blood, serum and pleural fluid not to disturb the patient's comfort.

Materials and Method

Fourier Transform Infrared Spectroscopy (FT-IR)

Infrared spectroscopy is a method based on the principle of absorption of the rays between the visible and microwave regions by the matter. As a result of the vibrational or rotational motion of a molecule, there must be a net change in the dipole moment of the molecule so that it can absorb infrared light. The region called infrared is divided into three regions: near (0.78 µm-2.5 µm), mid (2.5 µm-25 µm) and far infrared (25 µm-1000 µm). As a result of the absorption of infrared light, changes occur in the vibration and rotational movements of the molecule [13]. Molecular vibrations can be divided into two groups. The first is the stretching vibration, which is the vibration along the bond line, the continuous change of the distance between the atoms along the bond axis between two atoms. The second is bending vibration, the vibration along the plane, that is, the change of angle between the two bonds. While tensile vibration is of two types, symmetrical and asymmetrical, bending vibrations are of four types: shearing, shaking, oscillating and buckling.

The plot of infrared light intensity versus wave number is called an infrared spectrum. Infrared spectroscopy is a sensitive technique that allows obtaining structural and functional information resulting from the vibrations of the functional groups of the sample to be examined. The fingerprint information obtained allows the functional groups of molecules to be identified and thus distinguish their different structures. This information can be obtained by first making accurate band definitions and then calculating the location of the bands of interest, band intensities or the area under the bands and bandwidth values. The band intensity and area give information about the concentration of the substance. While band position provides information about order/disorder, bandwidth gives information about dynamics [14–16]. Thus, information about the bond types and functional groups in the structure of a compound can be obtained from the FTIR spectra. Therefore, it is possible to obtain much information such as determining the molecules in the system and their concentration. In line with this information, valuable information about biological systems can be obtained without damaging the sample used with FTIR spectroscopy [17, 18] (Figure 1).

Figure 1. FTIR Spectroscopy.

Chemometric analysis

Cancer diagnosis with FTIR spectroscopy is based on analyzing changes in the following parameters: The intensity of the bands in the spectra of the samples or the area under the band, their width and the shift in their positions. Multiple data generated by methods based on spectroscopy sometimes make it difficult to perform efficient analysis with known spectral analysis methods. Therefore, multivariate chemometric analyses are often needed to distinguish between groups and to determine specific spectral biomarkers. Statistical methods generally used in diagnosis and classification studies are divided into two main groups: unsupervised and supervised pattern identification methods.

Unsupervised pattern recognition methods

Unsupervised pattern recognition methods do not require prior knowledge of training data samples. Therefore, it allows the emergence of an unexpected grouping that has not been found before. Methods such as Principal Component Analysis (PCA) and cluster analysis are unsupervised pattern recognition methods. PCA provides important information in determining the relationships between different variables and thus explaining the relationship between samples. In short, it is widely used in interpreting the similarities or differences between samples. PCA aims to determine the best transformation to express the data at hand, which contains many interrelated variables with fewer variables. The ability to make more than one measurement on a single sample is called multivariate measurement. Low sensitivity to noise, reduced memory and capacity requirements, and more effective operation in small-dimensional spaces can be listed among the main advantages of PCA. Two graphs are obtained in the analysis method: score and loading graph. The score chart allows the investigation of relationships/variations between samples. On the other hand, the loading chart enables the analysis of which variables contribute to these variations and to what extent. Cluster analysis is a type of multivariate group technique whose primary purpose is to group groups based on their characteristics [19].

Supervised pattern recognition methods

Supervised pattern recognition methods require prior knowledge about classifying educational data samples. It separates the data according to previously defined groups and makes a sharper classification within the group boundaries. Linear Discriminant Analysis (LDA), Partial Least Squares Discriminant Analysis (PLS-DA), Soft Independent Modelling of Class Analogies (SIMCA) and Artificial Neural Networks (ANN) methods are supervised pattern recognition methods [20-24].

Discussion

Although techniques based on X-ray imaging are used to diagnose stomach cancer, the clinical use of these techniques is limited due to disagreements on diagnosis. Although biopsy-based histological and immune histochemical techniques are gold-standard, they are invasive and user-dependent. In recent years, it has been shown that the disease can be diagnosed with specific tumour markers in pleural fluid, serum and plasma. This study aimed to develop a method with high sensitivity and specificity that can be used in diagnosis by using the advantages of the combined use of FTIR spectroscopy and chemometric methods. Because pathological conditions such as diseases cause changes in the concentrations of biochemical components of biological fluids, the relative amounts of these components compared to each other, and their structures. These changes are reflected in the FTIR spectra.

Conclusion

FTIR spectroscopy enables the practical determination of these changes. However, developing a diagnostic method based on spectral changes is possible by evaluating these spectral data with multivariate analysis.

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Cite this article: Sahin, Y., et al. The Importance of Fourier-Transformed Infrared Spectroscopy (FT-IR) in the Diagnosis of Stomach Cancer. Eur J Clin Oncol, 2024, 6(1), 001-003