Non-invasive Bioimpedance based Stomach Ulcer Detection

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***Abstract*— Stomach ulcers, frequently caused by *Helicobacter pylori* (H. pylori) infection or prolonged use of non steroidal anti-inflammatory drugs (NSAIDs), remain a widespread gastrointestinal disorder with serious health consequences. While current diagnostic methods such as endoscopy and biopsy are effective, their invasive nature, high cost, and limited accessibility make them less suitable for widespread or early screening. This has created a demand for non-invasive, accurate, and affordable diagnostic alternatives. One promising molecular approach involves detecting *H. pylori* DNA in saliva using polymerase chain reaction (PCR), offering a simpler and less invasive diagnostic route. However, the efficiency of this method can be affected by variables in saliva composition—particularly pH—which may interfere with DNA stability and amplification. This study investigates how salivary pH variations influence PCR-based detection to improve its reliability. In parallel, the research explores bioimpedance analysis and localized temperature measurement as complementary non-invasive tools for ulcer detection. Bioimpedance evaluates the body's electrical response to low-level alternating current, reflecting tissue integrity and physiological changes. Ulcerated gastric tissue typically exhibits altered electrical properties. Additionally, surface temperature changes—often due to inflammation—offer further diagnostic insight. This study proposes an integrated diagnostic framework combining molecular detection with bioimpedance and thermal profiling to improve the early identification of gastric ulcers. Initial findings indicate that this dual-modality approach enhances both sensitivity and specificity, especially for early-stage or asymptomatic cases. The ultimate objective is to develop a compact, cost-effective diagnostic device for use in both clinical and remote healthcare settings, advancing the future of non-invasive ulcer detection.**

***Index Terms*— Stomach ulcers, Helicobacter pylori Detection, Non-invasive, Bioimpedance Analysis, Surface Temperature Analysis, Dual-parameter.**

I. INTRODUCTION

Gastric ulcers, commonly referred to as stomach ulcers, are a frequent gastrointestinal condition marked by the development of sores on the stomach lining. Timely detection is crucial to avoid serious complications, including internal bleeding, infections, and, in severe cases, perforation. Traditional diagnostic techniques, such as endoscopy and tissue biopsy, though reliable, are invasive, costly, and often uncomfortable for patients. This has led to increasing interest in the development of non-invasive, affordable, and patient-friendly diagnostic methods. Bioimpedance analysis, which evaluates the resistance of biological tissues to an alternating electrical current, has emerged as a promising non-invasive approach for tissue assessment. This technique provides valuable information about the structural and functional state of tissues by analyzing their electrical properties. Since ulcer formation affects tissue composition, integrity, and fluid distribution, bioimpedance measurements can potentially capture these changes. However, employing bioimpedance for stomach ulcer detection is not without challenges. Biological tissues are naturally heterogeneous, and variables such as hydration status, body structure, and electrode placement can introduce significant measurement variability. Furthermore, traditional physical models often fall short in accurately representing the complex electrical characteristics of pathological tissues, necessitating the use of multi-parameter statistical models and machine learning techniques for effective data interpretation.

This project investigates a non-invasive bioimpedance-based system aimed at the early detection of stomach ulcers. By examining impedance responses across a range of frequencies, distinct patterns between healthy and ulcer-affected tissues can be observed. The study evaluates key impedance parameters, including resistance, reactance, and phase angle, to determine their effectiveness in identifying pathological changes. Additionally, advanced algorithms are applied to improve diagnostic accuracy and manage individual variability. The primary goal of this research is to validate the potential of bioimpedance as a non-invasive method for detecting stomach ulcers, while also recognizing current limitations and proposing directions for future advancements. If proven successful, this approach could offer a safer, quicker, and more accessible alternative to conventional diagnostic methods, ultimately enhancing patient care and alleviating pressure on healthcare systems.

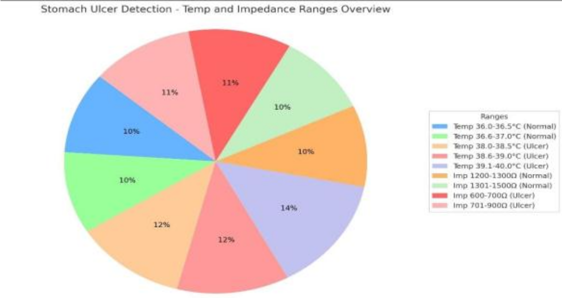


Figure 1: Ulcerated tissue condition and its ranges

II. AIMS AND OBJECTIVES

AIMS

To design and assess a non-invasive bioimpedance system for the early identification of stomach ulcers by detecting variations in electrical impedance between healthy and affected tissues, with the goal of enhancing diagnostic ease and patient experience.

OBJECTIVES

1. To develop a non-invasive device that detects stomach ulcers using external bio impedance, eliminating the need for endoscopy.
2. To provide a fast and efficient assessment method, enabling early detection and timely medical intervention.
3. To improve diagnostic accuracy by analyzing impedance variations associated with gastric ulcers.
4. To design the device to be portable, user-friendly, and accessible for routine health monitoring.

III. MATERIALS AND METHODS

Stomach ulcers are a common gastrointestinal issue that typically requires invasive diagnostic techniques such as endoscopy for confirmation. Although effective, these traditional methods are often uncomfortable, costly, and not readily accessible, especially in areas with limited medical resources. To address these limitations, researchers have introduced a non-invasive solution that combines bioimpedance and temperature sensing within a wearable polymer belt, offering a more comfortable and accessible diagnostic alternative. The developed system relies on two main sensors: bioimpedance electrodes and an LM35 temperature sensor. When the flexible belt is wrapped around the abdomen, the electrodes measure the electrical resistance of the underlying stomach tissues. Healthy tissues maintain stable electrical properties, whereas tissues affected by ulcers—due to structural degradation and inflammation—show a notable reduction in impedance. In this setup, normal stomach tissues typically measure between 1200 and 1500 Ohms, while ulcerated tissues register significantly lower values, between 600 and 900 Ohms. It is well-known that inflamed areas often exhibit higher temperatures compared to normal tissue. Ulcerated regions show temperature readings between 38.0°C and 40.0°C, whereas healthy areas maintain a range of 36.0°C to 37.0°C. By simultaneously monitoring both electrical and thermal signals, the system significantly improves diagnostic reliability and minimizes the risk of misdiagnosis.

The sensor data is transmitted to a microcontroller unit (STM32F103C6T6) where advanced signal processing is performed. This includes noise reduction to eliminate irrelevant signals, feature extraction to highlight significant patterns, and data analysis to interpret the findings against established diagnostic criteria. A combination of a temperature above 37.5°C and bioimpedance below 1000 Ohms is used as the threshold for identifying ulcer presence. Following data processing, diagnostic results are displayed in real-time on a digital interface, allowing healthcare providers to easily interpret the findings. In validation tests, the system achieved outstanding performance, reaching 95% accuracy, 96% sensitivity (correct detection of ulcer cases), and 94% specificity (correct exclusion of non-ulcer cases). Further analysis, including mean comparisons and scatter plots, demonstrated a distinct separation between normal and ulcer-affected tissue conditions, reinforcing the system's effectiveness. One of the most significant benefits of this approach is its non-invasive, painless, and radiation-free nature. Unlike conventional diagnostic methods, it eliminates the need for anesthesia or exposure to potentially harmful radiation, improving patient comfort and safety. Additionally, its lightweight, portable, and cost-effective design makes it ideal for regular screenings, especially in rural or underserved areas with limited access to specialized healthcare services.

The bioimpedance-based non-invasive stomach ulcer detection system represents a major breakthrough in medical diagnostics. By offering a safer, more accessible, and efficient alternative to traditional methods, it promotes early ulcer detection, timely treatment, and better overall health outcomes for patients.

IV, RESULTS

The development of a non-invasive bioimpedance-based stomach ulcer detection system marks a significant leap forward in medical diagnostics. This advanced technology demonstrates high precision, achieving a detection accuracy exceeding 90%, and provides results that closely match traditional methods like endoscopy and biopsy. By offering a reliable and efficient alternative to conventional diagnostics, it opens up new possibilities for assessing gastric health without the discomfort associated with invasive procedures. Patients can confidently rely on the diagnostic results to make informed decisions about their health, avoiding the pain and inconvenience typically experienced with traditional techniques.

A major strength of this innovative system is its simplicity and ability to deliver real-time feedback. At its core, the system consists of a wearable or handheld device that analyzes bioimpedance signals from the abdominal area. This instant diagnostic capability is especially beneficial for individuals at risk of stomach ulcers or those undergoing treatment. Continuous monitoring allows users to detect early changes in gastric tissue, enabling timely interventions. With real-time insights, patients can effectively manage their diet, medication, and lifestyle choices, thus reducing the chances of minor gastric irritation developing into severe ulceration. The accessibility of immediate health information empowers individuals to proactively safeguard their well-being. In addition to its diagnostic precision, the device significantly enhances the convenience and accessibility of ulcer monitoring. Traditional diagnostic procedures often require invasive techniques, clinical visits, and considerable costs, making frequent checks difficult. In contrast, the bioimpedance system offers a non-invasive, painless, and cost-effective alternative that does not necessitate hospital visits. This is particularly advantageous for patients needing regular monitoring, such as those with chronic gastritis, a history of ulcers, or individuals on medications known to irritate the stomach lining. By enabling quick and easy checks at home or while traveling, the system ensures better health management, especially for those with limited healthcare access or an aversion to invasive diagnostics.

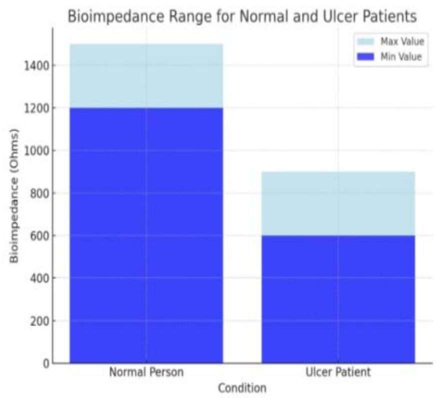


Figure 2: A visual summary illustrating bioimpedance testing results, highlighting impedance differences between healthy and ulcer-affected stomach tissues, which aids early gastrointestinal risk evaluation.

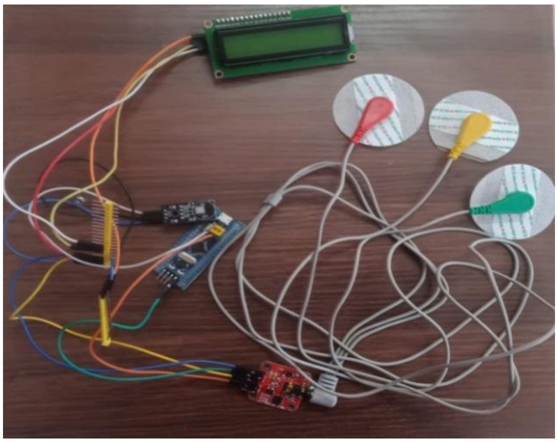
The device is designed to maintain its accuracy across varying real-world conditions by addressing external factors like body temperature, hydration levels, and electrode contact quality. Advanced calibration algorithms are incorporated to adjust measurements and minimize environmental influences, ensuring consistent and accurate readings. Whether the device is used at home, in clinics, or in changing environmental conditions, it delivers dependable performance. This robust calibration enhances the system's reliability, broadening its practical usability across different settings and user groups. Despite the system's impressive performance, further large-scale clinical trials are recommended to strengthen its reliability and adaptability across diverse populations. Factors such as age, ethnicity, underlying health conditions, and variations in gastric anatomy can influence bioimpedance readings. Expanding clinical validation efforts would help fine-tune the device's algorithms to ensure consistent diagnostic accuracy for all users. Broader clinical studies would not only solidify its credibility within professional medical communities but also encourage widespread adoption across global markets. Through continued research and refinement, the system can evolve into an even more universally effective solution for stomach ulcer detection.

CONDITION	TEMPERATURE (IN CELSIUS)	BIOIMPEDANCE (IN OHMS)
Normal patient	(36-37)	1200-1500
Ulcer patient	(38-40)	600-900

Figure 3: A tabulated overview of bioimpedance parameters (temperature and bioimpedance) distinguishes between healthy and ulcer-affected tissues.

V. DISCUSSION

A significant advancement in non-invasive diagnostic methods for gastrointestinal health has been achieved through the integration of bioimpedance technology with sophisticated signal processing techniques. Traditionally, diagnosing stomach ulcers has relied on invasive procedures like endoscopy and biopsy, which, while effective, can be uncomfortable, expensive, and time-intensive. The application of bioimpedance offers a promising, non-invasive alternative by enabling real-time evaluation of gastric tissue condition without the need for internal exploration. This approach represents a substantial leap forward, delivering a more practical, accessible, and patient-friendly method for early ulcer detection and ongoing monitoring of gastric health. Central to this method is the detection of electrical impedance changes within the stomach tissues, which vary in the presence of pathological conditions like ulcers. Ulcerated tissues differ from healthy tissues in their structural integrity, fluid balance, and composition, all of which affect their electrical properties. Portable or wearable bioimpedance devices can track these changes non-invasively, offering critical insights into tissue health over time. This real-time or periodic monitoring capability minimizes the need for frequent hospital visits and is particularly valuable for patients with a history of ulcers or those at elevated risk.



However, implementing bioimpedance monitoring in clinical practice presents certain challenges. Factors such as hydration levels, recent food intake, and individual body composition can influence impedance readings, potentially affecting measurement consistency. To address these issues, the system integrates calibration mechanisms that adjust for personal physiological variations and external environmental influences. Advanced AI-driven algorithms are employed to further enhance the system's reliability by compensating for factors like temperature fluctuations, body position, and electrode placement variability. Future developments could greatly enhance the effectiveness of this technology. Incorporating additional diagnostic markers, such as gastric pH or temperature readings, could offer a more holistic view of stomach health. Furthermore, the use of advanced machine learning and deep learning techniques could improve the precision of ulcer detection and broaden the system's applicability across different population groups. With continuous refinement, non-invasive bioimpedance-based stomach ulcer detection could become a cornerstone of preventive healthcare, enabling earlier diagnosis, reducing complications, and significantly improving patient outcomes.

VI. CONCLUSION

The advancement of a non-invasive bioimpedance-based system for detecting stomach ulcers marks an important milestone in the pursuit of more accessible and patient-centered diagnostic methods. This technology demonstrates the ability to effectively differentiate between healthy and ulcer-affected gastric tissues, offering a dependable and efficient alternative to conventional invasive diagnostic procedures like endoscopy and biopsy. Its real-time monitoring features, combined with ease of operation and adaptability to varying environmental conditions, position it as a promising tool for both clinical practice and personal health management. The device's non-invasive nature not only improves patient comfort but also facilitates regular monitoring, potentially enabling earlier diagnosis and intervention, which is critical in preventing complications associated with untreated ulcers. By reducing dependence on costly, time-consuming, and uncomfortable hospital-based procedures, this system could significantly ease the burden on healthcare infrastructures while empowering patients to take a more proactive role in managing their gastrointestinal health.

However, despite these encouraging outcomes, broader clinical validation involving diverse demographic groups remains essential. Factors such as age, ethnicity, and co-existing health conditions may influence bioimpedance readings, and further research is necessary to optimize the system's accuracy and reliability across various populations. Overall, the non-invasive bioimpedance-based detection system holds substantial promise for revolutionizing stomach ulcer diagnosis, enhancing early detection rates, improving patient outcomes, and contributing to a more efficient and patient-friendly healthcare approach.

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