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*RESEARCH ARTICLE*

# APPLICATION OF AMMONIA SENSORS IN ENDOSCOPY SYSTEMS FOR EARLY DETECTION OF HELICOBACTER PYLORI INFECTION

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## *Abstract*

H. pylori infection is one of the major causes that lead to the early diagnosis of gastritis and cancer. The main objective of this work was to present the integration of the ammonia sensor into endoscopes, which can be used for the local and real-time detection of H. pylori infection. For this purpose, the ammonia sensor was considered due to the fact that the amount of $NH_3$, which is produced by the activity of the urease enzyme, accurately reflects the presence of the infection, since the amount measured in the H. pylori positive samples differs significantly from the amount measured in the negative samples. The suggested sensor device includes the integration of the module into the distal end, which can provide stable gas molecule detection due to the presence of the selective semiconductor membrane in the acidic environment. The application of artificial intelligence-based processing of the real-time signal can lead to the automatic identification of the infection. The suggested method can provide improved accuracy in the diagnosis of the samples, even if the biopsy was not taken, thus speeding up the process and providing additional support for the early diagnosis of gastritis.



## Introduction:-

The development of modern medical technologies, especially the integration of artificial intelligence and sensor systems, has made it possible to perform diagnostic methods more accurately, quickly and non-invasively. Endoscopic diagnostics is at the heart of this development and is widely used in the visual and histological assessment of gastrointestinal diseases. However, the main limitation of traditional endoscopic approaches is that they are limited to visual observation and additionally require biopsy. Especially when detecting H. pylori infection and determining inflammatory processes at an early stage, these approaches may not be efficient in terms of both time and resources. H. pylori is one of the most common chronic bacterial infections in the world, and according to various studies, it infects about half of the world's population. Large-scale studies conducted in 2021 and 2023 showed that early detection and eradication of the infection can reduce the risk of developing gastric cancer by about 50%. This is especially effective when carried out before precursor lesions such as atrophy and intestinal metaplasia

have formed. A 2025 multicenter epidemiological study confirms that early diagnostic strategies are the most effective approach for preventive treatment in high-risk populations.

Although real-time analysis capabilities have been created in some devices (e.g. EndoFaster) in recent years, these systems are still not fully integrated into the endoscope and approaches based on gas analysis are limited. Direct integration of gas analyzers into endoscopes allows endoscopic evaluation to be performed not only on the basis of visual, but also on the basis of functional and biochemical indicators. This approach offers significant opportunities in terms of increasing diagnostic efficiency in clinical practice and reducing the need for invasive procedures.

**Significance of the Study:-**

Helicobacter pylori infection, which is one of the most important etiologic causes of gastrointestinal disease, exists in about half of the world's population and from 30% to 80% by region [1]. Unhygienic surroundings and socio-economic factors, mostly in developing countries, are reported to be the main causes of increasing the spread of this infection [2]. Since H. pylori infection plays an important role in the development of gastric and duodenal ulcers, chronic gastritis and gastric adenocarcinoma, its early and accurate diagnosis is considered a priority for global health [3]. The invasive techniques currently used (biopsy, histology, urease test) are time and operator-dependent methods, while non-invasive tests (breath test, serological analyses) are not combined with endoscopic evaluation [4]. Therefore, the development of sensor-integrated endoscopic systems capable of detecting H. pylori infection in real time, especially based on ammonia concentration, is of great scientific and clinical importance. Such systems both reduce invasiveness and provide more objective results by combining visual inspection with biochemical analysis.

Helicobacter pylori (H. pylori) infection is considered one of the main etiological factors of gastritis, at the root of inflammatory processes in the gastric mucosa. Detection of Helicobacter pylori infection plays an important role in the diagnosis of gastritis and other diseases diagnosis.

**TABLE 1: Association between H. pylori infection and various gastrointestinal pathologies.**

| Clinical condition | Incidence of H. pylori infection (%) |
|---|---|
| Non-atrophic gastritis | 85–100% |
| Duodenal ulcer | 90–95% |
| Gastric ulcer cases | 70–90% |
| Gastric adenocarcinoma (type I) | 60–80% |
| MALT lymphoma | 90% |

As can be seen in Table 1, H. pylori infection plays a major role in the development and growth of a broad spectrum of gastrointestinal pathology. The correlation is particularly high in non-atrophic gastritis and duodenal ulcer (85–100%), which indicates that the infection is one of the main causes of inflammatory diseases. Although the fact that the correlation is relatively low in gastric ulcer and gastric adenocarcinoma (70–90% and 60–80%), it is clear that H. pylori is involved in the pathogenesis of these diseases. This relationship suggests that infection is part of the pathogenesis of gastritis and its complications. [4]. Early detection of this bacterium plays an important role in the prevention of both symptomatic gastritis and its progression in a chronic form and more serious gastric pathology (e.g., gastric ulcer or adenocarcinoma). Early diagnosis of H. pylori, especially because of the access to invasive and non-invasive diagnostic methods, allows for more precise and effective therapeutic approaches in clinical practice. [5].

In recent decades, many scientific studies have been conducted on developing endoscopic diagnostic technologies. Most of the research has been targeted towards improving image quality, applying artificial intelligence, and recording more functional parameters. Furthermore, certain technologies have been proposed for the early diagnosis

of Helicobacter pylori infection, which is extremely common in the gastrointestinal tract. In this regard, the EndoFaster device, working on the principle of a real-time gas analyzer, measures the concentration of ammonia in a gastric content sample and, based on this indicator, allows you to determine the presence of Helicobacter pylori infection with high accuracy. The main advantage of the system is that it can provide diagnostic information during the endoscopic procedure without the need for invasive biopsy [6].

However, this technology is not yet directly integrated into existing endoscope systems, but is implemented as a separate modular device. Therefore, there are more technical configurations and procedure coordination needed in order for the system to work, which, in a sense, hinders its widespread application in clinical practice. Furthermore, since the device only works on the condition that a sample is taken from the antral region of the stomach, its diagnostic scope may also be limited. Therefore, in the future development of systems such as EndoFaster, integration into endoscopic devices in themselves, multi-point analysis features, and integration into artificial intelligence-based decision support systems can provide a more practical and beneficial clinical practice.

In addition, various non-invasive diagnostic methods, such as optical biosensors, FTIR spectroscopy, and urease breath tests, have been developed for the detection of H. pylori. However, these either do not depend on an endoscopic procedure (breath test) or require a sample of biopsy (FTIR), limiting their application as an end-to-end and real-time assessment in clinical settings. In this regard, the integration of gas-based sensors into the endoscope—in particular, localized measurement of ammonia levels—appears to be a promising alternative that both reduces invasiveness and provides more targeted information.

## Materials and Methods:-

The current systems of gas-based analyses, such as EndoFaster, are also provided in a module form independent of the endoscopic platform and cannot be used as an integral component of the endoscope. This reduces the simplicity and rapidity of the procedure. In addition, these systems do not allow for multipoint diagnostics and localized ammonia distribution mapping. All these limitations require the development of more functional and effective approaches.The proposed research aims to overcome the shortcomings of existing technologies by developing a sensor module that can be directly integrated into an endoscopic system for local ammonia detection. This approach can also provide a more objective and automated decision support system, supported by artificial intelligence-based signal processing [4].

One of the most important reasons scientifically behind the suitability of ammonia sensors is the metabolic properties of H. pylori. H. pylori possesses strong urease activity in the stomachal environment to hydrolyze urea into carbon dioxide and ammonia, which creates conditions favorable for the survival of the bacteria in an acid environment. It has been proven in research that ammonia concentration in gastric juice is well correlated with Helicobacter pylori infection, and the parameter is a good biomarker which can be quantified in real time [7].
The relationship between the H/pylori infection and the production of ammonia is illustrated in Figure 1.

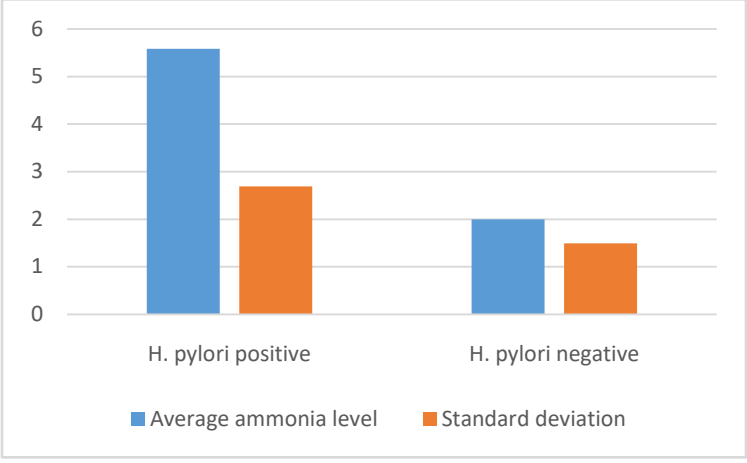


**Fig. 1: Relationship between H. pylori infection and production of ammonia.**

It has been observed that patients who test H. pylori-positive have significantly higher concentrations of ammonia in gastric juice. For example, in one study, the average ammonia level in the H. pylori-positive group was 850 ± 120 ppm, compared to 180 ± 60 ppm in the H. pylori-negative group, a difference that was statistically significant ($p < 0.0001$). This is closely associated with the bacterial enzyme activity of the urease. H. pylori urease breaks down the compound urea to form ammonia, which generates a localized rise in pH within the stomach that provides an appropriate environment for bacterial survival[8].

In addition, ammonia generated by H. pylori confers the survival advantage for the bacterium and at the same time triggers an inflammatory response of the gastric mucosa. This leads to damage in the gastric epithelium and subepithelial tissues, which are among the etiologic factors for chronic gastritis as well as other gastrointestinal diseases. From the graph, as it is observed, the level of ammonia in the H. pylori positive group on average measures as well as on variability significantly differ from the negative group. This indicates that the urease activity of the bacteria is directly related to individual differences and patient status.

Thus, it has been well established that H. pylori significantly increases ammonia levels in gastric juice and consequently affects the gastric environment, both clinically and scientifically. These results make it possible to evaluate ammonia concentration as a potential biomarker in H. pylori diagnostics and planning therapeutic strategies [9].This observation justifies the application of ammonia concentration as an H. pylori infection biomarker and offers a scientific rationale for the clinical use of real-time gas sensors for inclusion in endoscopic devices. In this regard, the integration of ammonia sensors into endoscopes can be considered a logical approach towards the development of real-time and non-invasive diagnostics. Consequently, ammonia sensors integrated into endoscopes can accelerate the detection of infection, minimize the need for biopsy, and reduce both the invasiveness and cost of the diagnostic process.

The integration of sensors, which provides real-time detection of gas-based biomarkers, i.e., ammonia, in endoscopic equipment is one of the directions of modern diagnostic development. To this purpose, the design concept for measuring the ammonia concentration, which is a biomarker for Helicobacter pylori infection, directly in the gastric cavity is proposed. In the theoretical model, placement of the sensor at the distal end of the endoscope enables it to perform both imaging and gas analysis simultaneously. Such an integration strategy, in contrast to existing modular designs, performs the measurement process directly in the imaging field, thereby improving diagnostic accuracy and speed of data analysis. Placing the sensor alongside the light and camera modules of the endoscope allows for synchronous collection of visual and chemical signals, which allows for the operational and non-invasive determination of metabolic changes associated with H. pylori. This design principle is a landmark step toward the direct integration of analysis technologies based on gas into the endoscopic design and is the theoretical and technological basis for future "smart endoscope" platform development.

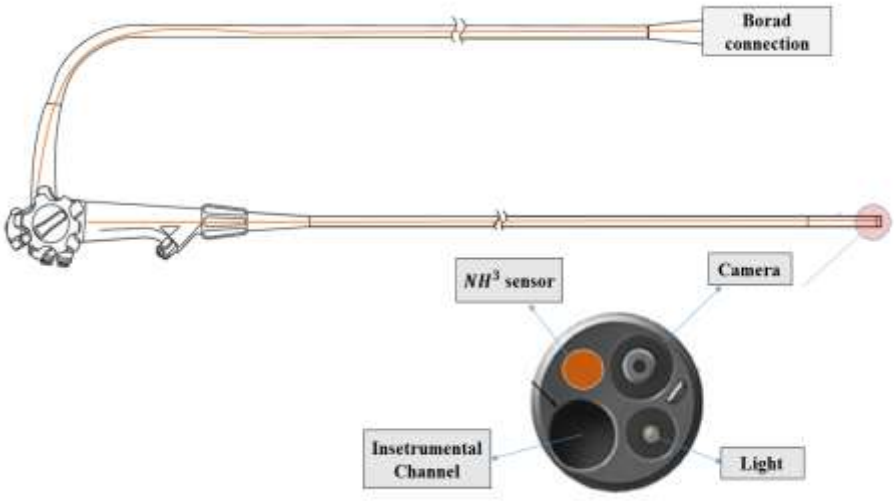


**Fig. 2: Schematic of $NH_3$ sensor placement at the distal end of the endoscope.**

The proposed scheme describes the functional working principle of the ammonia sensor integrated into the distal end of the endoscope and its role in the diagnostic process. The sensor measures the concentration of ammonia, one of the most important metabolic indicators of H. pylori infection, by analyzing the gases in the gastric lumen in real time. The data recorded is transmitted to the control unit of the endoscope, where, after initial filtration and correction, it is analyzed in an artificial intelligence-based module. The AI module compares the recorded data with reference values and estimates infection presence by probabilistic values. The above design offers a new generation system on the basis of combining functional and biochemical diagnostics with traditional endoscopic techniques limited only to direct vision.

Distribution of internal components and impact of sensor integration: Calculated area of an 8.0 mm inner diameter insertion tube internal is approximately 50.27 mm². The overall internal area of the given components — 2.8 mm biopsy channel, 2 mm air channel, 2 mm water channel, a 1.5 mm and a 2 mm optical fiber, 2 mm CCD cable, four 1.5 mm coil pipes and 2 mm $NH_3$ sensor — is ≈30.70 mm² in total (≈61.08% of internal area). Here, about 38.92% of the tube's interior space is left, i.e. ≈19.56 mm² is left for further construction, insulation and movement. The sensor's area is ≈3.14 mm², which is ≈6.25% of the inner area. These values show that the introduction of the sensor will not significantly impair the air-water channels, optical transmission and operation of the biopsy channel.
One of the major engineering advantages of the proposed system is the employment of a protective structure that ensures the sensor operates with certainty under the acidic and humid stomach environment. The structure adopts a semi-permeable membrane upon which gases (mainly ammonia molecules) can travel through but are prevented from coming in contact with liquid. This maintains the sensor's lifespan while keeping the signal quality constant. Additionally, the placement of the sensor at the distal end allows one to measure directly in the area where the gas concentration is highest within the antral region, increasing diagnostic accuracy.

Unlike traditional gas-based analysis systems, the proposed concept integrates gas detection directly into the functional architecture of the endoscope. The devices such as EndoFaster only analyze aspirated gastric content without taking spatial gas distribution into account. The system here is capable of supporting real-time measurement of local gas concentrations and facilitating ammonia mapping in the stomach. This feature opens up new prospects for the development of personalized treatment regimens for H. pylori.

## Results and Discussion:-

The geometric analysis of the endoscope insertion tube has proved that the integration of the ammonia ($NH_3$) sensor is possible without affecting the functionality of the existing components. For an endoscope with an inner insertion tube diameter of 8.0-10.0 mm, the total available cross-sectional area has been calculated to be about 50.27 mm². The total area occupied by standard internal components such as the biopsy channel, air-water channels, optical fibers, CCD cable, coiled tubes, and the proposed $NH_3$ sensor has been estimated to be 30.70 mm², accounting for 61.08% of the available internal area. Importantly, the area occupied by the $NH_3$ sensor alone is only ≈3.14 mm², accounting for ≈6.25% of the total internal area. Following the integration of all components, a free space of about 19.56 mm² (38.92%) is left, which is adequate for the purposes of insulation, mechanical support, and component movement.

The main aim of this proposed system is the real-time measurement of ammonia ($NH_3$), a specific metabolic biomarker of Helicobacter pylori infection. All decisions made regarding this system's design, spatial calculations, and integration strategies have been made with the specific aim of providing an accurate measurement of $NH_3$ in a localised fashion within the gastric lumen. The positioning of this sensor at the distal end of the endoscope maximises sensitivity while minimising signal dilution, as it is closer to the area of active urease production. Unlike other traditional gas analysis systems, which are based on gastric content aspiration, this system allows for the measurement of $NH_3$ in situ, thereby providing a higher degree of spatial information.

The calculated area of this sensor also indicates that, with the inclusion of this $NH_3$ detector, there is no compromise on endoscopic function while providing an appropriate level of exposure for this type of gaseous biomarker. This significant concentration difference, which is more than 4-fold, between H. pylori positive and negative cases suggests that $NH_3$ is not only detectable but also serves as a clinically discriminating parameter. As such, the proposed endoscopic system is not simply a generic gas sensor, but rather a biomarker-based diagnostic tool, specifically designed for the detection of H. pylori using the $NH_3$-based approach.

By focusing on the detection of $NH_3$ as the key diagnostic parameter, the proposed system is capable of facilitating the fast identification of the infection, as well as the use of AI-based analysis, thus bypassing the need for biopsy-based confirmation. Such a targeted approach towards the detection of H. pylori is a key step towards the development of functional, non-invasive, and metabolically based endoscopic diagnostics.

## Conclusion:-

The study proves that it is technically and clinically possible to integrate an ammonia ($NH_3$) detection-based sensor into endoscopic systems for the early and non-invasive detection of Helicobacter pylori infection. Geometric and systematic analysis proved that the integration of the $NH_3$ sensor into the distal end of the endoscope does not interfere with existing imaging, air-water, and biopsy endoscopic functions.The rationale for this study is based on the scientific understanding that ammonia, as a product of high urease activity of Helicobacter pylori, is a specific and measurable biomarker for this pathogen. The proposed system allows for the direct and real-time measurement of $NH_3$ within the endoscopic view, eliminating the limitation of classical endoscopic examination that is based on visual assessment.

In conclusion, it is proved that direct integration of $NH_3$-based gas biomarkers into endoscopic systems represents a promising approach for developing highly accurate real-time and non-invasive diagnostic tools for the early detection of Helicobacter pylori-associated gastritis and other gastric pathologies. This approach has the potential to improve the efficacy of clinical diagnostics, thus making an important contribution to the future development of modern endoscopic diagnostic technologies.

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