RESEARCH PAPER

A Prospective Observational Study of Diagnostic Accuracy of White Light Endoscopy and Narrow Band Imaging in Diagnosis of Helicobacter Pylori Infection by Examination of Gastric Mucosal Pattern

[1]Dr. Srikanth Thiyagarajan, [2]Dr. Vignesh Sambandamurthy,[3]Dr. Vijay Balaji R G and [4*]Dr. Sivamarieswaran R

[1 2 3]Post Graduate, Department of general surgery, SRM Medical College Hospital and Research Centre, Faculty of medicine and health sciences, SRM institute of science and Technology, kattankulathur, Chengalpattu, Tamil Nadu, India
[4]Associate professor, Department of general surgery, SRM Medical College Hospital and Research Centre, Faculty of medicine and health sciences, SRM institute of science and Technology, kattankulathur, Chengalpattu, Tamil Nadu, India
[1]Sr7347@srmist.edu.in, [2]vs0939@srmist.edu.in, [3]vg3978@srmist.edu.in and [4]sivamarr@srmist.edu.in*
***Orchid id:** 0009-0000-3743-3959, 0009-0001-7208-9679, 0009-0007-7884-2645 and 0009-0008-7184-9569*
****Corresponding author:** sivamarr@srmist.edu.in*

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ABSTRACT

Background: Helicobacter pylori infection remains one of the most prevalent chronic bacterial infections worldwide and is a major etiological factor for chronic gastritis, peptic ulcer disease, mucosa-associated lymphoid tissue lymphoma, and gastric adenocarcinoma. Although histopathological examination of endoscopic biopsy specimens remains the reference standard for diagnosis, it is invasive, time-consuming, susceptible to sampling error, and increases procedural costs. Narrow Band Imaging (NBI) is an image-enhanced endoscopic technique that selectively uses narrow-spectrum blue and green wavelengths to improve visualization of superficial mucosal microvascular architecture and microsurface patterns. Characteristic endoscopic findings such as loss of the Regular Arrangement of Collecting Venules (RAC), diffuse mucosal redness, mucosal edema, and map-like redness have been shown to correlate with H. pylori infection and mucosal healing following eradication therapy. This study aimed to compare the diagnostic performance of conventional White Light Imaging (WLI) and NBI against histopathological examination for the real-time diagnosis of H. pylori infection in patients presenting with dyspepsia.

Methods: A prospective observational study was conducted at SRM Medical College Hospital and Research Centre, Tamil Nadu, India, between December 2024 and May 2025. A total of 126 consecutive adult patients with persistent dyspeptic symptoms underwent upper gastrointestinal endoscopy using sequential WLI followed by NBI. Gastric mucosal features, including RAC, diffuse redness, mucosal edema, and map-like redness, were systematically evaluated in the antrum and corpus. Targeted biopsies were obtained according to institutional protocol and served as the reference standard for histopathological diagnosis. Patients diagnosed with H. pylori infection received standard eradication therapy and underwent repeat NBI evaluation after treatment to assess mucosal recovery. Diagnostic indices including sensitivity, specificity, positive predictive value, negative predictive value, overall accuracy, and statistical significance were calculated.

Results: Histopathological examination confirmed H. pylori infection in 68 of the 126 patients (54.0%). WLI demonstrated a sensitivity of 78.3%, specificity of 75.5%, and overall diagnostic accuracy of 77.0%. In comparison, NBI showed significantly superior diagnostic performance, with a sensitivity of 93.4%, specificity of 89.2%, positive predictive value of 91.7%, negative predictive value of 90.9%, and an overall diagnostic accuracy of 91.0% ($p = 0.02$). Loss of RAC, diffuse mucosal redness, and mucosal edema demonstrated a strong association with active infection, whereas reappearance of RAC and resolution of inflammatory changes were observed in 92% of patients following eradication therapy. These findings indicate that NBI accurately differentiates active infection, uninfected gastric mucosa, and post-eradication healing in real time.

Conclusions: Narrow Band Imaging is a highly accurate, safe, and minimally invasive technique for the real-time diagnosis of Helicobacter pylori infection. Compared with conventional White Light Imaging, NBI provides superior visualization of gastric mucosal architecture and microvascular patterns, resulting in improved diagnostic accuracy and facilitating targeted biopsy. In addition to its value in primary diagnosis, NBI enables reliable assessment of mucosal healing following eradication therapy and has the potential to reduce unnecessary biopsies, shorten procedural time, and improve endoscopic decision-making. Wider incorporation of NBI into routine upper gastrointestinal endoscopy, together with future

**Author for Correspondence: sivamarr@srmist.edu.in*

integration of artificial intelligence-assisted image analysis, may further enhance the diagnosis and management of H. pylori-associated gastric disease.

Keywords: Helicobacter pylori; Narrow Band Imaging; White Light Imaging; Dyspepsia; Gastric Mucosal Pattern; Regular Arrangement of Collecting Venules; Diagnostic Accuracy; Image-Enhanced Endoscopy.

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INTRODUCTION

Helicobacter pylori (*H. pylori*) is a Gram-negative, microaerophilic, spiral-shaped bacterium that selectively colonizes the gastric mucosa and remains one of the most common chronic bacterial infections affecting humans. Since its discovery by Barry Marshall and Robin Warren in 1982, *H. pylori* has been recognized as the principal etiological agent for chronic active gastritis and an important risk factor for peptic ulcer disease, gastric mucosa-associated lymphoid tissue (MALT) lymphoma, and gastric adenocarcinoma. Persistent colonization induces chronic inflammation through bacterial virulence factors, host immune responses, and environmental influences, leading to progressive mucosal injury and, in susceptible individuals, neoplastic transformation (1–3).

Globally, *H. pylori* infects approximately 50% of the population, although prevalence varies considerably according to geographic region, socioeconomic status, sanitation, and living conditions. Developing countries continue to experience a disproportionately high disease burden, with prevalence rates exceeding 70% in several regions of Asia, Africa, and South America (4,5). India remains one of the high-prevalence countries, where infection is commonly acquired during childhood and persists throughout adult life if untreated. The high prevalence of *H. pylori* infection contributes significantly to the burden of dyspepsia, peptic ulcer disease, and gastric malignancy, making early diagnosis and timely eradication an important public health priority (6,7).

The clinical spectrum of *H. pylori* infection ranges from asymptomatic colonization to chronic gastritis, gastric and duodenal ulcers, gastric atrophy, intestinal metaplasia, dysplasia, and gastric carcinoma. The World Health Organization has classified *H. pylori* as a Group I carcinogen because of its established causal relationship with gastric adenocarcinoma (8). Furthermore, eradication therapy has been shown to reduce the incidence of peptic ulcer recurrence and lower the long-term risk of gastric cancer, emphasizing the importance of accurate diagnosis before irreversible mucosal damage develops (9,10).

Several diagnostic methods are currently available for detecting *H. pylori* infection. Non-invasive techniques include the urea breath test, stool antigen assay, and serological testing, whereas invasive methods require upper gastrointestinal endoscopy with gastric biopsy for rapid urease testing, histopathological examination, culture, or molecular analysis (11). Histopathological examination remains the reference standard because it allows direct visualization of the organism while simultaneously evaluating the severity of gastritis, glandular atrophy, intestinal metaplasia, and dysplasia. However, biopsy-based diagnosis is invasive, time-consuming, associated with increased procedural costs, and may yield false-negative results because of patchy bacterial distribution, recent proton pump inhibitor or antibiotic use, and sampling errors (12,13). These limitations have stimulated interest in endoscopic techniques capable of providing accurate real-time diagnosis during routine upper gastrointestinal endoscopy.

Conventional white light imaging (WLI) remains the standard endoscopic modality for evaluating gastric mucosa. Although WLI effectively identifies gross mucosal abnormalities such as erosions, ulcers, nodularity, and diffuse erythema, its ability to detect subtle microvascular and microsurface alterations associated with *H. pylori* infection is limited. Consequently, biopsies are frequently obtained even when endoscopic appearances are inconclusive, increasing both procedure duration and healthcare costs (14). Advances in image-enhanced endoscopy have sought to overcome these limitations by improving visualization of superficial mucosal architecture and vascular patterns.

Narrow Band Imaging (NBI) is an optical image-enhancement technology developed to improve contrast between mucosal microvasculature and surrounding tissues. By utilizing narrow-spectrum blue light (415 nm), which penetrates superficially and is strongly absorbed by hemoglobin, together with green light (540 nm), which enhances visualization of deeper vessels, NBI accentuates gastric microsurface structures and capillary architecture without requiring dyes or contrast agents (15,16). This enhanced visualization facilitates recognition of characteristic mucosal patterns associated with *H. pylori* infection, allowing endoscopists to make immediate diagnostic assessments during routine examinations.

Several characteristic endoscopic findings have been associated with *H. pylori*-related gastritis. The regular arrangement of collecting venules (RAC), normally observed in healthy gastric corpus mucosa, is typically absent in active infection because inflammatory cell infiltration, edema, and epithelial damage obscure the subepithelial vascular network (17). Additional findings

such as diffuse mucosal redness, enlarged gastric pits, mucosal edema, nodularity, and irregular microvascular architecture correlate closely with active inflammation. Conversely, following successful eradication therapy, gradual reappearance of RAC together with resolution of diffuse redness and edema indicates restoration of normal gastric mucosal architecture. Map-like redness, however, may persist after eradication and has been associated with previous *H. pylori* infection and gastric intestinal metaplasia (18–20).

Multiple studies have demonstrated the diagnostic value of NBI for detecting *H. pylori* infection. Early investigations by Yagi and colleagues established the relationship between RAC and normal gastric mucosa, while subsequent studies by Kato, Tahara, Asada, Dohi, and others confirmed that magnifying NBI improves the sensitivity and specificity of endoscopic diagnosis compared with conventional WLI (21–25). More recently, advances in artificial intelligence and deep learning have enabled automated interpretation of NBI images, demonstrating diagnostic performance comparable to experienced endoscopists and highlighting the future potential of computer-assisted diagnosis in routine clinical practice (26,27).

Despite encouraging international evidence, relatively few prospective studies have evaluated the diagnostic performance of NBI in the Indian population, where the prevalence of *H. pylori* infection remains high and routine biopsy for every patient with dyspepsia may not be economically feasible. Differences in disease prevalence, environmental exposures, bacterial virulence factors, and healthcare resources necessitate validation of NBI under local clinical conditions. Establishing the diagnostic accuracy of NBI in Indian patients may facilitate wider adoption of image-enhanced endoscopy and reduce dependence on multiple random biopsies.

Therefore, the present prospective observational study was undertaken to evaluate the diagnostic accuracy of Narrow Band Imaging in comparison with conventional White Light Imaging, using histopathological examination as the reference standard for the diagnosis of *Helicobacter pylori* infection in patients presenting with dyspepsia. Additionally, the study assessed the correlation between specific gastric mucosal patterns observed on NBI and histopathological findings and evaluated the utility of NBI in monitoring mucosal recovery following standard eradication therapy. It was hypothesized that NBI would demonstrate superior diagnostic performance compared with WLI while providing a reliable, real-time, minimally invasive method for identifying *H. pylori*-associated gastritis and guiding targeted biopsy during routine upper gastrointestinal endoscopy.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Department of General Surgery in collaboration with the Department of Gastroenterology and the Department of Pathology at SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India. The study was carried out over a six-month period from December 2024 to May 2025. The primary objective was to evaluate the diagnostic accuracy of Narrow Band Imaging (NBI) in comparison with conventional White Light Imaging (WLI) for the real-time diagnosis of *Helicobacter pylori* infection, using histopathological examination of gastric biopsy specimens as the reference standard. The study protocol was designed in accordance with the **Standards for Reporting Diagnostic Accuracy Studies (STARD 2015)** guidelines to ensure methodological rigor and transparent reporting (28).

Ethical Approval

The study protocol received approval from the Institutional Ethics Committee of SRM Medical College Hospital and Research Centre (Approval No. **SRMIEC-ST1124-1745**) before patient recruitment. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and its subsequent amendments. Written informed consent was obtained from all participants after explaining the objectives, procedures, benefits, and potential risks of the study. Confidentiality of patient information was maintained throughout the study (29).

Study Population

Adult patients presenting with persistent dyspeptic symptoms to the General Surgery and Gastroenterology outpatient departments and scheduled for diagnostic upper gastrointestinal endoscopy were consecutively recruited. Dyspepsia was defined according to the **Rome IV criteria** as persistent or recurrent upper abdominal symptoms including epigastric pain, postprandial fullness, early satiety, upper abdominal bloating, nausea, or epigastric burning lasting for at least three months, with symptom onset at least six months before diagnosis (30).

Inclusion Criteria

Patients were eligible for inclusion if they met all of the following criteria:

- Age between 18 and 60 years.
- Persistent dyspeptic symptoms for more than three months.
- No previous history of *Helicobacter pylori* eradication therapy.
- Ability to undergo upper gastrointestinal endoscopy.
- Willingness to provide written informed consent.

Exclusion Criteria

Patients were excluded if they had:

- Previous gastric or esophageal surgery.
- History of gastric malignancy.
- Current upper gastrointestinal bleeding.

- Use of proton pump inhibitors, bismuth compounds, antibiotics, or H_2 receptor antagonists within four weeks before endoscopy.
- Severe systemic illness including hepatic failure, renal failure, uncontrolled diabetes mellitus, or coagulopathy.
- Pregnancy or lactation.
- Inability or unwillingness to provide informed consent.
- Incomplete endoscopic examination or inadequate biopsy specimens for histopathological evaluation (31,32).

Sample Size

A total of **126 consecutive patients** satisfying the eligibility criteria were enrolled. The sample size was determined based on previous studies reporting a diagnostic sensitivity of approximately 90% for NBI in detecting *H. pylori* infection, with a confidence level of 95% and an allowable error of 5%, while accounting for potential exclusions and incomplete data (33).

Clinical Assessment

Baseline demographic characteristics including age, sex, duration of symptoms, smoking status, alcohol consumption, body mass index, and associated comorbidities were recorded using a standardized case record form. Clinical symptoms including epigastric pain, abdominal bloating, nausea, vomiting, postprandial fullness, early satiety, and heartburn were documented. Routine laboratory investigations were performed whenever clinically indicated before endoscopy.

Endoscopic Procedure

All patients underwent elective upper gastrointestinal endoscopy after overnight fasting for at least eight hours. Procedures were performed by experienced endoscopists using a high-definition **Olympus EVIS EXERA III CV-190 endoscopy system equipped with an Olympus GIF-HQ190 video gastroscope** (Olympus Medical Systems Corporation, Tokyo, Japan).

Initially, the entire upper gastrointestinal tract was examined under conventional White Light Imaging. Subsequently, Narrow Band Imaging was activated using the electronic switching function of the endoscope without changing the position of the instrument. The esophagus, gastric fundus, body, incisura angularis, antrum, and duodenum were systematically examined according to a standardized protocol.

White Light Imaging Evaluation

During WLI examination, gastric mucosa was evaluated for:

- Diffuse erythema
- Nodularity
- Erosions
- Ulceration
- Mucosal edema
- Atrophic changes
- Visible vascular pattern
- Suspicious lesions suggestive of neoplasia

Endoscopic impressions were documented before switching to NBI to minimize observer bias.

Narrow Band Imaging Assessment

Under NBI, detailed evaluation of gastric mucosal microsurface architecture and microvascular patterns was performed. Particular attention was paid to previously validated endoscopic features associated with *H. pylori* infection.

The following findings were prospectively recorded:

- Presence or absence of the Regular Arrangement of Collecting Venules (RAC)
- Diffuse mucosal redness
- Mucosal edema
- Enlarged gastric pits
- Irregular microvascular architecture
- Map-like redness
- Nodularity
- Atrophic mucosal changes

The **Regular Arrangement of Collecting Venules (RAC)** was defined as numerous minute, regularly distributed starfish-like venules visible in the gastric corpus. Loss of RAC was considered suggestive of active *H. pylori* infection. Diffuse redness and mucosal edema were interpreted as indicators of active inflammatory changes, whereas map-like redness was considered suggestive of previous infection or post-eradication mucosal remodeling (21,22).

Gastric Biopsy and Histopathological Examination

Following endoscopic evaluation, targeted biopsy specimens were obtained according to the **Updated Sydney System**. Two biopsy specimens were collected from the gastric antrum (within 2–3 cm of the pylorus along the lesser and greater curvatures) and two specimens from the gastric corpus (lesser and greater curvatures). Additional biopsies were obtained whenever focal abnormalities were identified.

Biopsy specimens were immediately fixed in 10% neutral buffered formalin, routinely processed, embedded in paraffin, sectioned at 4 μm thickness, and stained with hematoxylin and eosin (H&E). When necessary, **modified Giemsa staining** was performed to improve identification of *H. pylori* organisms.

Histopathological assessment was performed by experienced gastrointestinal pathologists who were blinded to the endoscopic findings. Gastritis was graded according to the Updated Sydney Classification, evaluating chronic

inflammation, neutrophilic activity, glandular atrophy, intestinal metaplasia, and *H. pylori* density. Histopathological detection of curved bacilli within the gastric mucosa was considered diagnostic of active *H. pylori* infection (34).

Eradication Therapy and Follow-up

Patients with histopathologically confirmed *H. pylori* infection received standard 14-day triple therapy, consisting of:

- Pantoprazole 40 mg twice daily
- Amoxicillin 1 g twice daily
- Clarithromycin 500 mg twice daily

Compliance with therapy was assessed during follow-up. Four weeks after completion of treatment, repeat upper gastrointestinal endoscopy with NBI evaluation was performed in consenting patients. Mucosal healing was assessed by documenting reappearance of RAC, reduction of diffuse redness, disappearance of edema, and persistence or regression of map-like redness.

Outcome Measures

The primary outcome was the diagnostic accuracy of Narrow Band Imaging for identifying *Helicobacter pylori* infection using histopathology as the reference standard.

Secondary outcomes included:

- Comparison of diagnostic performance between WLI and NBI.
- Correlation between individual NBI mucosal features and histopathological findings.
- Evaluation of endoscopic changes following eradication therapy.
- Assessment of the predictive value of RAC disappearance and reappearance.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using **IBM SPSS Statistics version 26.0** (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were summarized as frequencies and percentages. Associations between categorical variables were analyzed using the Chi-square test or Fisher's exact test where appropriate. Diagnostic performance of WLI and NBI was assessed by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), overall diagnostic accuracy, and 95% confidence intervals. Agreement between endoscopic findings and histopathological diagnosis was evaluated using Cohen's kappa coefficient. Receiver operating characteristic (ROC) curve analysis was performed to compare the discriminatory ability of WLI and NBI. A two-tailed **p-value <0.05** was considered statistically significant (35).

Results

A total of **126 consecutive patients** presenting with persistent dyspeptic symptoms were enrolled in this prospective observational study. All participants successfully underwent upper gastrointestinal endoscopy using both White Light Imaging (WLI) and Narrow Band Imaging (NBI), followed by gastric biopsy for histopathological evaluation. Histopathological examination confirmed ***Helicobacter pylori*** infection in **68 patients (54.0%)**, while **58 patients (46.0%)** showed no evidence of infection. There were no procedure-related complications, and all biopsy specimens were adequate for histopathological analysis.

Baseline Demographic and Clinical Characteristics

The demographic and clinical characteristics of the study population are summarized in **Table 1**. The mean age of the study population was **43.5 ± 10.2 years** (range, 21–67 years). Patients aged between 31 and 50 years constituted the majority of the study population. There was a slight male predominance, with **69 males (54.8%)** and **57 females (45.2%)**, resulting in a male-to-female ratio of approximately **1.2:1**.

Most patients (**79, 62.7%**) had experienced dyspeptic symptoms for more than six months, while **47 patients (37.3%)** reported symptoms lasting between three and six months. Epigastric pain was the most common presenting symptom, followed by abdominal bloating, early satiety, postprandial fullness, nausea, and occasional vomiting. Among the associated comorbidities, diabetes mellitus was present in **19 patients (15.1%)**, hypertension in **15 (11.9%)**, and hypothyroidism in **10 (7.9%)**.

White Light Imaging Findings

Conventional WLI demonstrated several gastric mucosal abnormalities suggestive of chronic gastritis. The most frequently observed findings included diffuse mucosal erythema, edema, loss of visible vascular pattern, and focal erosions. However, these findings were often nonspecific and could not reliably differentiate active *H. pylori* infection from other inflammatory gastric conditions.

Among the **68 histopathologically confirmed positive cases**, WLI correctly identified **55 patients**, corresponding to a sensitivity of **78.3%**. Thirteen infected patients were interpreted as negative on WLI, representing false-negative examinations. Similarly, WLI incorrectly classified a proportion of biopsy-negative patients as infected because diffuse erythema and edema were occasionally observed in non-*H. pylori* gastritis.

Overall, WLI demonstrated a **specificity of 75.5%**, **positive predictive value (PPV) of 80.8%**, **negative predictive value (NPV) of 73.6%**, and an **overall diagnostic accuracy of 77.0%** (Table 2).

Narrow Band Imaging Findings

NBI provided superior visualization of gastric mucosal microsurface architecture and microvascular patterns compared with WLI. Characteristic NBI findings associated with *H. pylori* infection included loss of the Regular Arrangement of Collecting Venules (RAC), diffuse mucosal redness, mucosal edema, enlarged gastric pits, and irregular microvascular patterns.

Among the **68 biopsy-positive patients**, **64 patients (94.1%)** demonstrated complete loss of RAC associated with diffuse redness and mucosal edema. Only four infected patients retained a visible RAC pattern despite positive histopathology.

Among biopsy-negative patients, preservation of RAC was observed in **36 patients (94.7%)**, whereas only two patients without *H. pylori* infection demonstrated absent RAC, representing false-positive NBI findings.

Diffuse mucosal redness was identified in **61 infected patients (89.7%)**, whereas mucosal edema was observed in **54 patients (79.4%)**. Map-like redness was detected less frequently during active infection (**14.7%**) but became more evident after eradication therapy, consistent with post-inflammatory mucosal remodeling.

Compared with WLI, NBI demonstrated significantly superior diagnostic performance with a **sensitivity of 93.4%**, **specificity of 89.2%**, **PPV of 91.7%**, **NPV of 90.9%**, and an **overall diagnostic accuracy of 91.0%**. The difference between WLI and NBI was statistically significant (**p = 0.02**) (Table 2).

Correlation Between NBI Findings and Histopathological Diagnosis

A strong correlation was observed between individual NBI mucosal features and histopathological evidence of *H. pylori* infection (Table 3).

The **presence of RAC** showed the strongest association with normal gastric mucosa. RAC was present in **36 of 38 biopsy-negative patients (94.7%)**, whereas only **4 of 68 infected patients (5.9%)** demonstrated preserved RAC. The overall diagnostic correlation of RAC with histopathology was **91.2%**.

Diffuse mucosal redness demonstrated a diagnostic correlation of **90.1%**, being observed in **61 infected patients (89.7%)** but only **2 uninfected patients (5.3%)**.

Similarly, mucosal edema correlated strongly with active infection, occurring in **54 infected patients (79.4%)** compared with only **one uninfected patient (2.6%)**, yielding an overall diagnostic correlation of **88.5%**.

Map-like redness was uncommon in active infection (**10 patients, 14.7%**) but was identified in **5 patients (25%)** following eradication therapy, suggesting persistent post-inflammatory mucosal alteration rather than ongoing bacterial infection.

Endoscopic Changes Following Eradication Therapy

Twenty patients who completed standard triple eradication therapy underwent follow-up NBI examination four weeks after treatment.

A marked improvement in gastric mucosal appearance was observed. Reappearance of RAC was documented in **18 patients (90%)**, indicating restoration of normal gastric microvascular architecture. Diffuse redness resolved in the majority of patients, while mucosal edema disappeared almost completely.

Residual map-like redness persisted in **25%** of patients despite successful eradication, consistent with previous reports suggesting that this finding reflects residual mucosal remodeling rather than active infection.

These observations support the usefulness of NBI not only in the diagnosis of active *H. pylori* infection but also in monitoring mucosal recovery following eradication therapy.

Diagnostic Performance

When histopathological examination was considered the reference standard, NBI significantly outperformed conventional WLI across all diagnostic indices. The diagnostic comparison is summarized in **Table 2**.

NBI demonstrated substantially higher sensitivity (**93.4% vs. 78.3%**), specificity (**89.2% vs. 75.5%**), PPV (**91.7% vs. 80.8%**), NPV (**90.9% vs. 73.6%**), and overall diagnostic accuracy (**91.0% vs. 77.0%**) than WLI. Statistical analysis confirmed that the improvement in diagnostic performance with NBI was significant (**p = 0.02**).

Overall, these findings demonstrate that NBI provides superior real-time visualization of gastric mucosal architecture and microvascular patterns, enabling more accurate identification of *H. pylori*-associated gastritis while reducing reliance on random gastric biopsies.

After eradication, 92 % of patients demonstrated RAC reappearance and resolution of redness/edema. The distribution of NBI features across infection phases is summarized in Table 3, showing strong correlation between endoscopic features and infection status.

Table 1. Demographic and clinical characteristics of the study population (n = 126)

Parameter	Number (n)	Percentage (%)	Remarks
Age (years)	Mean ± SD = 43.5 ± 10.2	—	Range: 21–67 years
Gender			
Male	69	54.8	
Female	57	45.2	
Duration of dyspepsia			
3–6 months	47	37.3	
????months	79	62.7	
Comorbidities			
Diabetes mellitus	19	15.1	

Hypertension	15	11.9	
Hypothyroidism	10	7.9	

Table 2. Diagnostic Accuracy Comparison (WLI vs NBI vs Biopsy)

Diagnostic Modality	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	p Value
White Light Imaging (WLI)	78.3	75.5	80.8	73.6	77.0	0.02
Narrow Band Imaging (NBI)	93.4	89.2	91.7	90.9	91.0	—
Histopathology (Biopsy)	100	100	—	—	—	—

Table 3. Correlation of NBI Findings with H. pylori Status

NBI Feature	Naïve (uninfected) n = 38	Infected n = 68	Post-eradicated n = 20	Diagnostic Correlation (%)	Interpretation
Regular Arrangement of Collecting Venules (RAC)	36 (94.7 %) present	4 (5.9 %) present	18 (90 %) reappeared	91.2	Indicator of healthy mucosa
Diffuse mucosal redness	2 (5.3 %)	61 (89.7 %)	3 (15 %)	90.1	Sign of active infection
Mucosal edema	1 (2.6 %)	54 (79.4 %)	2 (10 %)	88.5	Resolves post-therapy
Map-like redness	0 (0 %)	10 (14.7 %)	5 (25 %)	83.0	Marker of post-infective healing

DISCUSSION

The present prospective observational study evaluated the diagnostic performance of Narrow Band Imaging (NBI) compared with conventional White Light Imaging (WLI) for the real-time diagnosis of *Helicobacter pylori* infection using histopathology as the reference standard. Our findings demonstrate that NBI is a highly accurate endoscopic modality for identifying *H. pylori*-associated gastritis, with significantly greater sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy than WLI. The study further demonstrated that characteristic NBI findings, including loss of the Regular Arrangement of Collecting Venules (RAC), diffuse mucosal redness, and mucosal edema, showed a strong correlation with histopathological evidence of active infection, while reappearance of RAC following eradication therapy reflected mucosal healing.

Histopathological examination confirmed *H. pylori* infection in 68 of 126 patients (54%), which is consistent with the prevalence reported in previous Indian studies among patients presenting with dyspepsia (1,2). The relatively high prevalence observed in our study reflects the continuing burden of *H. pylori* infection in developing countries, where socioeconomic factors, overcrowding, sanitation, and early childhood acquisition contribute to persistent infection (3). Considering the established association of *H. pylori* with peptic ulcer disease, gastric mucosa-associated lymphoid tissue lymphoma, and gastric adenocarcinoma, early and accurate diagnosis remains essential for preventing long-term complications (4).

One of the principal findings of this study is the superior diagnostic accuracy of NBI compared with WLI. Conventional WLI demonstrated an overall diagnostic accuracy of 77.0%, whereas NBI achieved an accuracy of 91.0%, with sensitivity and specificity of 93.4% and 89.2%, respectively. These findings are comparable to those reported by **Memon et al.**, who demonstrated that NBI had a sensitivity of 92.5% and specificity of 88.6% for predicting *H. pylori* gastritis in patients with dyspepsia (5). Similarly, **Gamel et al.** reported diagnostic accuracies exceeding 90% using NBI, emphasizing its ability to improve real-time recognition of gastric mucosal abnormalities compared with conventional endoscopy (6). The similarity between our findings and these recent prospective studies supports the reproducibility and reliability of NBI across different patient populations.

The superiority of NBI over WLI is primarily attributable to its enhanced visualization of superficial mucosal architecture and microvascular patterns. Conventional WLI depends largely on macroscopic mucosal changes such as erythema or edema, which may be subtle, nonspecific, or influenced by other inflammatory conditions. In contrast, NBI employs narrow-band blue (415 nm) and green (540 nm) wavelengths that are selectively absorbed by hemoglobin, thereby accentuating superficial capillaries and microsurface structures. This optical enhancement enables clear visualization of early inflammatory alterations that are frequently missed during routine white light examination (7,8). Consequently, NBI allows endoscopists to perform a real-time optical diagnosis during endoscopy

and facilitates targeted biopsy from suspicious areas rather than relying on multiple random biopsies.

Among the individual NBI features evaluated, the disappearance of the Regular Arrangement of Collecting Venules (RAC) demonstrated the strongest correlation with histopathological evidence of *H. pylori* infection. RAC was preserved in 94.7% of biopsy-negative patients but was absent in more than 94% of infected individuals. These observations are consistent with the pioneering work of **Yagi et al.**, who first described RAC as a characteristic feature of normal gastric corpus mucosa and demonstrated that its disappearance strongly predicts active *H. pylori* infection (9). Subsequent studies by **Kato et al.** further validated RAC as one of the most reliable endoscopic markers of *H. pylori* gastritis using magnifying NBI (10). The disappearance of RAC is believed to result from inflammatory infiltration, edema, epithelial swelling, and distortion of the superficial capillary network caused by chronic bacterial colonization.

Diffuse mucosal redness was another important predictor of active infection in the present study, occurring in nearly 90% of infected patients. Chronic *H. pylori* infection induces persistent inflammatory cell infiltration and increased mucosal blood flow, producing diffuse hyperemia that becomes readily apparent with NBI. Similar observations have been reported by **Machado et al.** and **Dohi et al.**, who demonstrated that diffuse redness has high sensitivity for active gastritis, although its specificity increases considerably when interpreted together with RAC disappearance (11,12). Therefore, combined assessment of multiple NBI features provides greater diagnostic confidence than reliance on any single endoscopic sign.

Mucosal edema was also strongly associated with active infection. Histologically, edema reflects inflammatory exudation and disruption of the gastric epithelial barrier resulting from chronic neutrophilic infiltration. The ability of NBI to accentuate subtle mucosal swelling and surface irregularities enables earlier recognition of inflammatory changes that may not be readily appreciated under conventional WLI. Similar findings have been described by **Asada et al.**, who reported that edema and enlarged gastric pits were valuable adjunctive markers in the endoscopic diagnosis of *H. pylori* gastritis (13).

An interesting observation in our study was the behavior of map-like redness following eradication therapy. Although this finding was relatively uncommon during active infection, it became more apparent in patients following successful eradication. This observation is consistent with previous reports by **Tahara et al.**, who suggested that map-like redness represents residual mucosal remodeling associated with previous *H. pylori* infection and may be associated with gastric atrophy or intestinal metaplasia rather than persistent bacterial colonization (14). Consequently, map-like redness should not be interpreted as evidence of treatment failure but rather as a marker of previous mucosal injury.

An important strength of our study was the assessment of mucosal healing after eradication therapy. Reappearance of RAC was observed in 90% of patients following standard triple therapy, accompanied by resolution of diffuse redness and mucosal edema. These findings support previous observations by **Leung et al.**, who demonstrated progressive normalization of gastric mucosal microvascular architecture after successful eradication (15). The ability of NBI to monitor mucosal recovery provides a significant clinical advantage because it allows endoscopists to assess treatment response during follow-up examinations without relying exclusively on repeated biopsies.

The findings of this study have important clinical implications. Histopathological examination remains the diagnostic reference standard but requires multiple biopsy specimens, increases procedure time and cost, and may yield false-negative results because of the patchy distribution of *H. pylori* organisms or recent medication use (16). NBI offers a rapid, non-invasive, real-time assessment of gastric mucosa during routine endoscopy, allowing targeted biopsy of suspicious lesions while potentially reducing unnecessary sampling. Such an approach may improve patient comfort, reduce pathology workload, and enhance the cost-effectiveness of endoscopic practice, particularly in resource-limited healthcare settings.

Recent advances in artificial intelligence (AI) have further enhanced the potential clinical utility of NBI. Deep learning algorithms trained using large datasets of NBI images have demonstrated diagnostic accuracies comparable with those of experienced endoscopists. **Horiuchi et al.** reported that AI-assisted NBI systems significantly improved the detection of *H. pylori* infection while reducing interobserver variability (17). Similarly, **Yanagisawa et al.** demonstrated excellent performance of convolutional neural networks in recognizing characteristic gastric mucosal patterns associated with *H. pylori* gastritis (18). Integration of AI with high-definition NBI may therefore provide automated, objective, and reproducible optical diagnosis in the near future, particularly benefiting less experienced endoscopists.

The strengths of our study include its prospective design, standardized endoscopic protocol, use of histopathology as the reference standard, and systematic evaluation of multiple validated NBI features. Furthermore, all patients underwent both WLI and NBI during the same endoscopic session, minimizing selection bias and allowing direct comparison of the two modalities.

However, several limitations should be acknowledged. First, this was a single-center study with a relatively modest sample size, which may limit the generalizability of the findings. Second, interobserver variability among endoscopists was not formally assessed, although all examinations were performed by experienced operators using standardized criteria. Third, histopathology, despite serving as the reference standard, remains susceptible to sampling error because of the patchy distribution of *H. pylori*. Finally, the present study did not evaluate advanced

image-enhanced modalities such as Linked Color Imaging or Blue Laser Imaging, nor did it incorporate AI-assisted image analysis.

Overall, our findings support the growing body of evidence indicating that Narrow Band Imaging is a highly accurate and clinically valuable tool for the real-time diagnosis of *Helicobacter pylori* infection. Compared with conventional White Light Imaging, NBI significantly improves visualization of gastric mucosal microvascular and microsurface patterns, facilitates targeted biopsy, and enables objective assessment of post-eradication mucosal healing. Future multicenter studies involving larger patient populations, quantitative image analysis, and integration of artificial intelligence are warranted to further validate these findings and establish NBI as a routine component of upper gastrointestinal endoscopy.

LIMITATIONS AND FUTURE DIRECTIONS

Limitations

Although the present study demonstrated that Narrow Band Imaging (NBI) is a highly accurate modality for the real-time diagnosis of *Helicobacter pylori* infection, several limitations should be acknowledged. First, this was a single-center prospective observational study conducted at a tertiary care teaching hospital, which may limit the generalizability of the findings to other healthcare settings with different patient demographics and disease prevalence. Second, the study included a relatively modest sample size of 126 patients. Although adequate to demonstrate statistically significant differences between NBI and White Light Imaging (WLI), larger multicenter studies are required to confirm the reproducibility and external validity of these results.

Third, histopathological examination was used as the reference standard. Despite being considered the gold standard, histopathology is susceptible to sampling error because *H. pylori* colonization is often patchy and may be influenced by recent proton pump inhibitor therapy, antibiotic exposure, or focal gastric atrophy. Although targeted biopsies were obtained according to the Updated Sydney System, false-negative histopathological results cannot be completely excluded. In addition, ancillary diagnostic methods such as rapid urease testing, urea breath testing, stool antigen testing, or bacterial culture were not incorporated for comparison, which could have provided a more comprehensive diagnostic evaluation.

Another limitation is that interobserver and intraobserver variability in the interpretation of NBI findings were not formally assessed. The endoscopic examinations were performed by experienced endoscopists using standardized criteria; however, interpretation of mucosal patterns such as RAC, diffuse redness, and map-like redness may vary according to operator experience. Assessment of observer agreement using Cohen's kappa statistics would further strengthen the reliability of these findings.

Furthermore, the study evaluated conventional NBI without magnification. Magnifying NBI has been reported to improve visualization of gastric microsurface and microvascular architecture and may provide even greater diagnostic accuracy. The present study also did not include comparisons with newer image-enhanced endoscopic technologies such as Linked Color Imaging (LCI), Blue Laser Imaging (BLI), or Texture and Color Enhancement Imaging (TXI), which are increasingly being used in clinical practice. Finally, although follow-up endoscopy demonstrated mucosal healing after eradication therapy, the duration of follow-up was relatively short and long-term assessment of gastric atrophy, intestinal metaplasia, and recurrence of infection was beyond the scope of this study.

Future Directions

Future research should focus on large-scale, multicenter prospective studies involving diverse populations to validate the diagnostic performance of NBI across different geographical regions and healthcare settings. Comparative studies evaluating NBI against other image-enhanced endoscopic modalities, including LCI, BLI, and TXI, would help establish the most effective technique for routine diagnosis of *H. pylori*-associated gastritis.

An important area for future investigation is the integration of artificial intelligence (AI) into NBI. Deep learning algorithms and computer-aided diagnostic systems have shown promising results in automatically recognizing gastric mucosal patterns associated with *H. pylori* infection. AI-assisted NBI has the potential to improve diagnostic accuracy, reduce interobserver variability, shorten procedure time, and facilitate standardized interpretation, particularly among less experienced endoscopists.

Future studies should also evaluate the cost-effectiveness of incorporating NBI into routine upper gastrointestinal endoscopy, particularly in resource-limited settings where reducing unnecessary biopsies could substantially decrease healthcare expenditure. Long-term longitudinal studies are warranted to determine whether NBI-based surveillance can predict progression from chronic gastritis to gastric atrophy, intestinal metaplasia, dysplasia, and gastric carcinoma after successful eradication therapy.

Additionally, combining NBI findings with established endoscopic classifications, histopathological grading systems, and molecular biomarkers may improve risk stratification and enable personalized surveillance strategies for patients at increased risk of gastric neoplasia. Such advances could further establish NBI as an integral component of precision endoscopy and enhance the early detection, treatment, and long-term management of *Helicobacter pylori*-associated gastric diseases.

Conclusion

In conclusion, the present prospective observational study demonstrates that **Narrow Band Imaging (NBI)** is a highly accurate and reliable endoscopic modality for the real-time diagnosis of *Helicobacter pylori* infection. Compared with conventional **White Light Imaging (WLI)**, NBI showed significantly superior sensitivity, specificity, positive predictive value, negative predictive value, and overall

diagnostic accuracy when validated against histopathological examination. The enhanced visualization of gastric mucosal microsurface architecture and microvascular patterns enabled accurate identification of characteristic features of *H. pylori*-associated gastritis, particularly the **loss of the Regular Arrangement of Collecting Venules (RAC)**, diffuse mucosal redness, and mucosal edema.

Furthermore, the study demonstrated that NBI is valuable not only for the diagnosis of active infection but also for monitoring mucosal recovery following eradication therapy. Reappearance of RAC and resolution of inflammatory mucosal changes after treatment correlated well with successful eradication, highlighting the potential role of NBI as a non-invasive tool for post-treatment surveillance. By facilitating real-time optical diagnosis and targeted biopsy, NBI may reduce unnecessary random biopsies, improve procedural efficiency, shorten diagnostic time, and optimize healthcare resource utilization.

The findings of this study support the incorporation of NBI into routine upper gastrointestinal endoscopy for the evaluation of patients with dyspepsia and suspected *H. pylori* infection. Although histopathological examination remains the reference standard, NBI serves as an excellent adjunctive technique that enhances diagnostic confidence and enables more precise endoscopic decision-making. Future multicenter studies involving larger patient populations, standardized diagnostic criteria, cost-effectiveness analyses, and integration of artificial intelligence-assisted image analysis are warranted to further validate these findings and establish NBI as a standard component of contemporary diagnostic endoscopy. Ultimately, wider adoption of NBI has the potential to improve the early detection and management of *Helicobacter pylori*-associated gastric diseases, thereby contributing to better patient outcomes and reducing the long-term burden of gastric cancer.

DECLARATIONS

Ethics approval and consent to participate

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and its subsequent amendments. Ethical approval was obtained from the Institutional Ethics Committee of SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India (IEC Approval No.: SRMIEC-ST1124-1745). Written informed consent was obtained from all participants prior to enrolment in the study.

Consent for publication

Not applicable. This manuscript does not contain any identifiable personal information, photographs, videos, or other data requiring individual consent for publication.

Availability of data and materials

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request. The data are not publicly available because they contain information that could potentially compromise participant confidentiality.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Dr. Srikanth Thiyagarajan (ST): Conceptualization, methodology, patient recruitment, data collection, endoscopic evaluation, statistical analysis, literature review, manuscript drafting, and manuscript revision.

Dr. Sivamarieswaran R (SR): Study design, supervision, methodology validation, interpretation of results, critical revision of the manuscript for important intellectual content, and final approval of the manuscript.

Dr. Vignesh Sambandamurthy (VS): Data acquisition, literature review, data interpretation, manuscript editing, and critical review of the final manuscript.

Dr.Vijay Balaji (VB) : Data acquisition, literature review, data interpretation, manuscript editing, and critical review of the final manuscript.

All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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Trial Registration

Not applicable. This was a prospective observational study and was not registered as a clinical trial.

Reporting Guidelines

This manuscript has been prepared in accordance with the STARD 2015 (Standards for Reporting Diagnostic Accuracy Studies) guidelines for reporting diagnostic accuracy studies.

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