Linked color imaging improves endoscopic diagnosis of active *Helicobacter pylori* infection

**Authors**
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We retrospectively ana-
Patients and methods

Patients

This was a single-center retrospective study conducted in the Department of Molecular Gastroenterology and Hepatology, Kyoto Prefectural University of Medicine. The study was approved by the University Ethical Review Committee and performed out in accordance with the Helsinki Declaration of the World Medical Association. In addition, this study was registered in the University Hospital Medical Information Network Clinical Trials Registry (UMIN-CTR) as number UMIN0000021674. All patients provided written informed consents to undergo esophagogastroduodenoscopy (EGD) using both WLI and LCI at the University Hospital, Kyoto Prefectural University of Medicine.

Consecutive patients who underwent EGD and following examinations to determine their H. pylori infection status between October 2013 and October 2014 at the University Hospital, Kyoto Prefectural University of Medicine, were selected for this study. We evaluated both patients with H. pylori infection and those who tested negative for H. pylori infection after eradication therapy in order to evaluate and compare whether LCI and WLI could detect diffuse redness and diagnose H. pylori infection accurately. The presence of H. pylori infection was determined by histologic examination, the rapid urease test (PyloriTek®; Serim Research Corp., Elkhart, IN, USA), serum antibody test, or 13C-urea breath test (UBit®; Otsuka, Tokyo, Japan). The absence of H. pylori infection was determined by the 13C-urea breath test and histological examination at least 2 months after H. pylori eradication therapy. The following patients were excluded from this study: (1) patients without H. pylori infection and without atrophic mucosa; (2) patients with histories of H. pylori eradication within the previous 1 year; (3) patients with histories of gastric surgery; and (4) patients with severe liver, renal, cardiopulmonary dysfunction, or blood disease including severe anemia.

Endoscopic imaging

All examinations were carried out with a high-definition EG-L590WR endoscope corresponding to the LASEREO endoscopic system (FUJIFILM Co., Tokyo, Japan). In brief, this LASEREO system uses a semiconductor laser as the light source and has narrow-band light observation functions, BLI and LCI, without a customized optical filter. It uses 2 types of lasers, with 410-nm and 450-nm wavelengths. Both bandwidths are <2nm, in contrast to the bandwidth for NBI (30nm) [10]. The laser with a 450-nm wavelength produces irradiated phosphor with an illumination similar to that produced by a xenon lamp. The combination of strong laser light with a wavelength of 450-nm and fluorescent light provides illumination that is almost equivalent to that of WLI. LCI is a new image-enhanced technology that is intended to enhance slight color differences in the red region in the mucosa. This mode is based on the image captured under similar light conditions in BLI-bright; however, further post-image processing is later applied so that the slightly reddish color becomes much redder and slightly whitish color becomes much whiter than the colors appear under WLI (Fig. 1). Ultimately, LCI improves the ability of the observer to recognize slight differences in mucosal color such as from inflammation or atrophy, compared to that with conventional WLI. WLI and LCI images were selected from the antegrade and retroflex views of the gastric body.

In the case of H. pylori infectious gastritis, WLI shows a slight redish mucosa in the entire fundic gland (Fig. 2a and Fig. 2b), while LCI shows a deep reddish (crimson) mucosa in the entire fundic gland (Fig. 3a and Fig. 3b). In the cases of H. pylori-negative stomach after eradication therapy, WLI shows an orange/yellow mucosa in the entire fundic gland (Fig. 4a and Fig. 4b), while LCI shows a light orange (white apricot) mucosa in the entire fundic gland (Fig. 5a and Fig. 5b).

Participating endoscopists

Four endoscopists who were blinded to the clinical data evaluated all endoscopic images. None of them performed the EGDs in this study. Two expert endoscopists (expert A and B) had previously performed over 10,000 conventional EGDs, while the other 2 were non-expert endoscopists (non-expert C and D) who had previously performed less than 2000 conventional EGDs.

Diagnostic evaluation

Four endoscopists evaluated the images of the gastric fundic areas from the antegrade and retroflex views using each endoscopic modality (WLI and LCI). Images obtained with each modality were prepared for evaluation by placing them on a slide and...
displaying them independently of the images obtained with the other endoscopic modality (Fig. 2 and Fig. 3). The criterion for diagnosing *H. pylori* infection using both WLI and LCI was the presence of diffuse redness of the fundic mucosa. Using WLI, the diagnostic criterion of *H. pylori* infection is a marked or slight redness involving the entire mucosa of the fundic gland, while using LCI, the diagnostic criterion is a deep red (crimson) color also involving the entire mucosa of the fundic gland.

In an independent experiment, we examined the interobserver and intraobserver variabilities of the endoscopists diagnosing *H. pylori* infection. All 4 endoscopists diagnosed the images from each case in the order of presentation in 1 day. One month later, the same images were presented in a different order for diagnosis by the same endoscopists.

**Calculation of sample size**

We evaluated the diagnostic differences in determining for *H. pylori* infection between WLI and LCI by the McNemar test in a pilot study of 24 patients. LCI was superior to WLI for diagnosing *H. pylori* infection in 8 patients (33%), and the McNemar’s odds ratio of LCI for WLI was 4.0. Thus, we needed 20 participants in order to detect the significant differences in diagnostic results with a probability (Power) of 0.8 and α error of 0.05. Because the proportion of patients with a different diagnosis in the re-
response of matched pairs was 33%, the required sample size was set to 60 patients (=20/0.33).

Statistical analysis
Continuous variables, such as patient age, were analyzed with the Mann-Whitney U test. Comparisons of incidences between 2 groups such as sex and atrophic border, were analyzed with Pearson’s chi-squared test or Fisher’s exact test. McNemar’s test was used to compare diagnostic accuracy, sensitivity, and specificity between WLI and LCI. The diagnostic accuracy of each method is presented as a percentage. The Wilson score method was used to measure the 95% confidence interval. Interobserver variability was quantified using the kappa statistic, which measures agreement over and above chance agreement. Kappa values of < 0.20, 0.21 – 0.40, 0.41 – 0.60, 0.61 – 0.80 and > 0.80 are considered to indicate poor, fair, moderate, good and excellent agreement, respectively. P<0.05 was considered statistically significant. All statistical analyses were performed using SPSS software, Version 22.0 for Windows (IBM Japan, Ltd, Tokyo, Japan).

Results
A total of 60 patients were evaluated in this study between October 2013 and October 2014. There were 30 patients with *H. pylori* infection and 30 patients who tested negative for *H. pylori* infection after eradication therapy. The clinical features of the patients are summarized in Table 1.

The mean accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for LCI diagnoses for the 4 endoscopists were 85.8%, 93.3%, 78.3%, 81.2%, and 92.2%, respectively. On the other hand, the mean accuracy, sensitivity, specificity, PPV, and NPV for WLI diagnoses among the mean of 4 endoscopists were 74.2%, 81.7%, 66.7%, 70.6%, and 75.5%, respectively. The accuracy and sensitivity for LCI were significantly higher than those for WLI (P=0.002 and P=0.011, respectively). The performance data from the 4 endoscopists are shown in Table 2. The accuracy, sensitivity, specificity, NPV and PPV for LCI were higher for both experts and non-experts compared with WLI.

The kappa values of interobserver variability between the four endoscopists for WLI were fair to moderate. The kappa values of interobserver variability between the 4 endoscopists for LCI were as follows: expert to expert was excellent; the others were moderate to good (Table 3). The kappa values of intraobserver variability for WLI were as follows: A and D were good, B was fair, and C was moderate. The kappa values of intraobserver variability for LCI were:

Table 1  Clinical features of patients.

<table>
<thead>
<tr>
<th>Atrophic border</th>
<th>Gender</th>
<th>Male</th>
<th>H. pylori-positive</th>
<th>Female</th>
<th>H. pylori-negative</th>
<th>n.s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>O-1, O-2</td>
<td></td>
<td>22</td>
<td>17</td>
<td></td>
<td>22</td>
<td>17</td>
</tr>
<tr>
<td>O-3</td>
<td></td>
<td>3</td>
<td>4</td>
<td></td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

1 Kimura-Takemoto classification system.
variability for LCI were as follows: A and B were excellent, and the others were good (Table 4). The kappa values of interobserver and intraobserver variability for LCI were higher than those for WLI between all of the 4 endoscopists. In 7 cases with severe atrophic mucosa (O-3), there were 3 false-negative cases of LCI diagnosis by all 4 endoscopists. In those cases, LCI showed no diffuse redness due to severe atrophic change of gastric corpus. Those are limitations of LCI diagnosis.

To our knowledge, this is the first report to compare the usefulness of LCI for diagnosing H. pylori infection to that of WLI. Endoscopic diagnosis of H. pylori infection in gastric mucosa has been established. A regular arrangement of collecting venules is an endoscopic feature with high sensitivity and high specificity for detecting H. pylori-negative normal stomachs [11–13]. Studies using magnifying endoscopy or confocal laser endomicroscopy have shown endoscopic features associated with histopathologic findings related to H. pylori infection [14,15]. However, it was very difficult to observe and diagnose H. pylori infection using these methods, and assessment of endoscopic findings depended on the skill level of the endoscopists.

Endoscopic findings, such as diffuse or spotty redness, mucosal swelling, and swelling of the gastric area, can be used as diagnostic indices for H. pylori infection [8]. Diffuse redness in the fundic gland mucosa on histology was considered to reflect mucosal hyperemia due to inflammatory changes [16]. A strong correlation with an objective index of redness, the hemoglobin index (IHb), has been reported, suggesting that diffuse redness is the most important feature for diagnosing H. pylori infection [17]. Therefore, we hypothesized that LCI would detect diffuse redness more easily than would WLI.

The aim of our study was to evaluate whether LCI could detect this diffuse redness and diagnose H. pylori infection more accurately than could WLI. We excluded patients who did not have H. pylori infection, or atrophic mucosa, because the diagnostic accuracy of H. pylori infection by WLI is so high in these patients [8]. Therefore, we evaluated H. pylori infection status between H. pylori-positive patients and H. pylori-negative patients with atrophic mucosa after eradication.

The diagnostic accuracy of both experts and non-experts using LCI was superior to those for WLI. However, the kappa values for interobserver variability of LCI for comparisons between experts and non-experts or non-experts and non-experts was <0.50, which showed only moderate agreement. This was due to the use of recorded images and lack of experience of all endoscopists with LCI. Therefore, all endoscopists should practice LCI in real time. Biopsy-based methods for diagnosing H. pylori infection, such as the rapid urease test, histology, and bacterial culture, have a low sensitivity [18]. The accuracy of biopsy-based diagnosis using the Updated Sydney System [19] was dependent on the local mucosal conditions of the biopsy sites. If the biopsy specimens are taken at sites of atrophic mucosa and intestinal metaplasia, biopsy-based diagnosis may show false-negative results.

LCI can evaluate the whole fundic gland area compared with biopsy-based methods. However, there were 3 false-negative cases of LCI diagnosis by all 4 endoscopists. In those cases, LCI showed no diffuse redness due to severe atrophic change of gastric corpus. Those are limitations of LCI diagnosis.

Our study has limitations. First, the number of patients was small and the data are from a single center. Second, this study is a limited evaluation of recorded images in selected patients. Third, the relationship between LCI and the Updated Sydney System was not assessed in this study. Therefore, WLI and LCI examination combined with the Updated Sydney System will be needed for further multi-institutional studies with a large number of cases. In conclusion, LCI can identify active H. pylori infection by emphasizing the diffuse redness of fundic gland mucosa. These results suggest that LCI improves endoscopic diagnostic accuracy of H. pylori infection compared with WLI.

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Acknowledgements

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Table 3 Interobserver variability between expert and non-expert endoscopists.

<table>
<thead>
<tr>
<th>Endoscopist</th>
<th>A to B</th>
<th>A to C</th>
<th>A to D</th>
<th>B to C</th>
<th>B to D</th>
<th>C to D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappa values for WLI</td>
<td>0.24</td>
<td>0.39</td>
<td>0.37</td>
<td>0.37</td>
<td>0.49</td>
<td>0.28</td>
</tr>
<tr>
<td>Kappa values for LCI</td>
<td>0.85</td>
<td>0.45</td>
<td>0.75</td>
<td>0.45</td>
<td>0.75</td>
<td>0.45</td>
</tr>
</tbody>
</table>

WLI, white light imaging; LCI, linked color imaging.

Table 4 Intraobserver variability among 4r endoscopists.

<table>
<thead>
<tr>
<th>Endoscopist</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappa values for WLI</td>
<td>0.73</td>
<td>0.39</td>
<td>0.47</td>
<td>0.64</td>
</tr>
<tr>
<td>Kappa values for LCI</td>
<td>0.82</td>
<td>0.83</td>
<td>0.74</td>
<td>0.79</td>
</tr>
</tbody>
</table>

WLI, white light imaging; LCI, linked color imaging.
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2 Perez-Perez GI, Rothenbacher D, Brenner H. Epidemiology of Helicobacter pylori infection. Helicobacter 2004; 9 (Suppl. 01): 1–6
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