ORIGINAL ARTICLE

Computed virtual chromoendoscopy system (FICE): A new tool for upper endoscopy?

Chromoendoscopie virtuelle FICE : gadget ou outil utile à la pratique de l’endoscopie digestive haute ?

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Available online 19 March 2008

Summary

Objectives. — A newly developed computed virtual chromoendoscopy system, Fuji Intelligent Color Enhancement (FICE) technology, decomposes images by wavelength, then directly produces reconstructed images with enhanced mucosal surface contrast. The aims of the present study were to determine the quality of information provided by computed virtual chromoendoscopy for detecting gastrointestinal polyps and to identify the best channel setting for imaging.

Patients and methods. — Thirty-one upper endoscopy procedures were performed in 31 patients using Fujinon 1.3-million-pixel endoscopes with zoom. A polyp was diagnosed in 45% of the patients. Six experienced endoscopists, who had never used the computed virtual chromoendoscopy system before, analysed the 31 endoscopy reports. Each endoscopy report included 11 images (one conventional image and one image for each FICE channel). The endoscopists used a 10-cm analog visual scale to determine the three best FICE channels, and to evaluate the quality and pit pattern of the chromoendoscopy images.

Results. — Channel 4 (red: 520; green: 500; blue: 405) was considered the best channel in 39.7% of the reports (p < 0.0001) and was among the best three in 77%. For 94.1% of the reports, the best FICE channel image was considered superior to the conventional image (p < 0.0001). Median pit pattern score was 9.43 for computed virtual chromoendoscopy and 7.08 for conventional endoscopy (p < 0.001).

Conclusion. — Fuji Intelligent Color Enhancement (FICE) channel 4 images were significantly better than conventional images. Computed virtual chromoendoscopy enabled better analysis of the pit pattern and the normal-pathological mucosal junction. Computed virtual chromoendoscopy can be used to identify gastroduodenal polyps and to assist in complete polypectomy.

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Résumé
But du travail. — Nous avons réalisé une étude évaluant une nouvelle technique de chromoendoscopie « virtuelle » (Fujinon Intelligent Color Enhancement [FICE]) qui amplifie les différences de contraste de la muqueuse. La technologie FICE repose sur la séparation de l'image initiale, la mise en place d’une filtration virtuelle et la reconstitution instantanée de l’image ainsi modifiée. Dix réglages sont prédéfinis en fonction des longueurs d’ondes rouge, verte et bleue. Le but de notre étude était d’évaluer la qualité de l’image en chromoendoscopie virtuelle et de rechercher le meilleur réglage dans l’exploration de la pathologie gastroduodénale.

Patients et méthodes. — Trente-et-une observations ont été réalisées chez 31 patients en utilisant un appareil Fujinon de 1,3 millions de pixels avec un zoom. Ces 31 observations ont été présentées à six endoscopistes n’ayant jamais utilisé le logiciel de chromoendoscopie virtuelle. Dans 45 % des cas un polype a été identifié. Chaque observation comprenait 11 images (une spontanée et une pour chacun des dix réglages). Les critères d’évaluation ont été, premièrement, l’identification des trois meilleurs réglages, deuxièmement, leur qualité par rapport à l’image spontanée, troisièmement, la qualité du pit-pattern et quatrièmement, la qualité des limites muqueuse saine – muqueuse pathologique. Le score évaluant la qualité de l’image, la qualité du pit-pattern et la qualité de la limite zone pathologique – zone normale était construit d’après une échelle visuelle analogique de 0 à 10.

Résultats. — Le réglage 4 (rouge : 520 ; vert : 500 ; bleu : 405) était classé comme le meilleur réglage dans 39,7 % des cas (p < 0,0001) et était retenu dans 77 % des cas parmi les trois meilleurs réglages. Le meilleur réglage de chaque observation (quelque soit le réglage) était considéré dans 94,1 % des cas comme supérieur à l’image spontanée (p < 0,0001). La valeur médiane appréciant la qualité du pit-pattern était de 9,43 pour l’image de chromoendoscopie virtuelle et de 7,08 pour l’image spontanée (p < 0,001).

Conclusion. — Le réglage 4 du FICE donne de façon significative une image de qualité supérieure à l’image conventionnelle. Le FICE permet une meilleure analyse du pit-pattern et de la jonction zone pathologique-muqueuse normale. La chromoendoscopie « virtuelle » peut être utilisée pour apprécier les caractéristiques des polypes gastriques et duodénaux et devrait permettre leur résection dans des meilleures conditions techniques.

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Introduction

Fuji Intelligent Color Enhancement (FICE), a recently developed virtual chromoendoscopic system, can simulate an infinite number of wavelengths in real time. The system has 10 channels that are designed to explore the entire mucosal surface (of structures and vessels). Each channel corresponds to three specific wavelength filters (red, green and blue), but no one setting is specifically used for a given gastroduodenal condition. Virtual chromoendoscopy can be used to identify gastric lesions, accurately measure their size and obtain high-quality topographical diagnoses.

Gastric or duodenal adenomas are preneoplastic lesions [1]. The diagnosis of gastric cancer or adenomas with severe dysplasia is a difficult task; in general, the endoscopic appearance is type la in the Japanese classification of superficial lesions. Staining techniques with 0.4% indigo carmine could be useful for detecting fine mucosal irregularities. In Japan, chromoendoscopic techniques, mainly with methylene blue, are used for early detection of gastric lesions. Shaw et al. demonstrated the usefulness of chromoendoscopy to facilitate the diagnosis of gastric lesions [2,3]. Among the 93 chromoendoscopies performed in an at-risk population for gastric cancer, 24 presented mucosal lesions, including six (25%) missed on conventional endoscopy [2]. Chromoendoscopy is not widely used in France, but the development of an instantaneous chromoendoscopy technique could facilitate its use.

To date, the superiority of the “virtual” chromoendoscopic image over the standard image of normal gastric mucosa or gastric polyps has not been demonstrated in a randomized comparative study.

The purpose of the present study was to compare the standard endoscopic image with the FICE virtual endoscopic image in terms of image quality, pit pattern and the appearance of the normal-pathological mucosal junction. A further goal was to determine which FICE channel settings provided the best yield for gastroduodenal explorations.

Methods

The FICE system

The FICE system, manufactured by Fujinon Corporation (Saitama, Japan), was developed by Professor Y. Miyake at Chiba University in Japan. Briefly, the software applies an algorithm to the real-time endoscopic image, which is deconstructed to determine a wavelength for each of three colors (red, green and blue) (Fig. 1). After changing the wavelengths with virtual electronic filters, the image is reconstructed instantaneously. The penetration of light into the mucosa varies according to the wavelength: those in the 400–500 nm range are ideal for analyzing surface structures (Fig. 2) whereas, because of the absorption properties of hemoglobin, longer wavelengths of about 550 nm are
Figure 1  Mechanism of light spectral decomposition by FICE.
Mécanisme de décomposition spectrale de la lumière selon le système FICE.

Figure 2  Images displayed differently according to each level of wavelength (from 400 to 700 nm).
Modification de l’image spectrale en fonction de la longueur d’onde (de 400 à 700 nm).

Table 1  Spectral specification of each computed virtual chromoendoscopy.
Caractéristiques des variations spectrales du logiciel de chromoendoscopie virtuelle.

<table>
<thead>
<tr>
<th>Ten FICE channels</th>
<th>Red</th>
<th>Green</th>
<th>Blue</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>FICE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>500</td>
<td>445</td>
<td>415</td>
<td>Mucosal and vessel structure: esophagus</td>
</tr>
<tr>
<td>1</td>
<td>500</td>
<td>470</td>
<td>420</td>
<td>Mucosal and vessel structure: esophagus</td>
</tr>
<tr>
<td>2</td>
<td>550</td>
<td>500</td>
<td>470</td>
<td>Vessel structure: esophagus</td>
</tr>
<tr>
<td>3</td>
<td>540</td>
<td>490</td>
<td>420</td>
<td>Detection of colonic polyps</td>
</tr>
<tr>
<td>4</td>
<td>520</td>
<td>500</td>
<td>405</td>
<td>Colonic polyps (polyps capillaries and surface)</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>480</td>
<td>420</td>
<td>Colonic polyps (polyps capillaries and surface)</td>
</tr>
<tr>
<td>6</td>
<td>580</td>
<td>250</td>
<td>460</td>
<td>Detection of colonic polyps</td>
</tr>
<tr>
<td>7</td>
<td>520</td>
<td>450</td>
<td>400</td>
<td>Detection of colonic polyps</td>
</tr>
<tr>
<td>8</td>
<td>540</td>
<td>415</td>
<td>415</td>
<td>Narrow band imaging</td>
</tr>
<tr>
<td>9</td>
<td>550</td>
<td>500</td>
<td>400</td>
<td>Esophageal vessels, regeneration of the gastric mucosal epithelium</td>
</tr>
</tbody>
</table>
more effective for visualizing blood vessels. With real-time electronic wavelength manipulation, an infinite number of combinations can be used to create reconstructed images. Ten channels with different predefined absorption wavelengths are available (Table 1).

Endoscopy procedures

Thirty-one upper endoscopy procedures were performed by a single operator (SC) in 31 patients: 17 explorations reached the duodenum and 14, the stomach. All were performed under general anesthesia with a Fujinon 1.3-million-pixel EG490ZW5 gastroscope with a flexible tip. The results were normal for 17 procedures (55%) and polyps were identified in 14 (45%).

Using ×20 to ×30 magnifications, the operator recorded three standard images and 30 FICE images (three images per channel), then selected the best image for each setting. The endoscopy report thus included 11 images — one standard image and one image for each of the 10 FICE channels (Fig. 3).

Image assessment

Six experienced endoscopists (with more than 3000 gastroscopy procedures among them), who had never used the
FICE upper endoscopy

FICE system before, participated in the evaluation, completing a standard datasheet for each of the 31 procedures. The physicians were asked to select the three best images among the 10 FICE images, and then to decide whether or not the quality was better than the standard image. A 10-cm visual analog scale was used to score (from 0 to 10) overall image quality, pit pattern and quality of the normal–pathological mucosal junction.

Statistical analysis

Results were analyzed by a non-endoscopy member of the team who was blinded to the channel settings, numbered 0 to 9. Intergroup comparisons (standard versus FICE images) were performed to determine the best FICE channel, image quality and pit pattern to distinguish pathological from normal mucosa. Differences were considered significant at \( p < 0.05 \) (Wilcoxon’s test).

For the standard image and the three best FICE images of each endoscopy report, image quality, pit-pattern quality, and distinction between pathological and normal mucosa were scored with the 10-cm visual analog scale. Statistical comparison was performed using Wilcoxon’s test.

Results

Best FICE channels

The best FICE channels were selected independently of the area visualized and the presence or not of polyps. No significant difference was found between the duodenum and the stomach. The best FICE setting for upper gastrointestinal endoscopy was channel 4 \( (p < 0.0001) \). This setting was considered the best for 39.7% of the reports. Considering the three channels chosen as best by the endoscopists for each of the 31 procedures, the top-ranking channels were: channel 4 (among the best three channels in 76.6% of the reports), channel 7 (26.8%) and channel 0 (24.8%) (Table 2).

FICE versus standard image

The quality of the FICE image was found to be superior to that of the spontaneous image in 95% of the procedures. Considering all channel settings, the endoscopists rated the best FICE image as superior to the standard image in 94.1% of the procedures and equivalent in 5.8%.

Quality of the FICE image

The quality of the FICE and standard images was scored on a visual analog scale. The endoscopists considered that the standard images were of good quality. The average score attributed to the standard images was 7.37 (range 2–10). On identifying the best FICE image for each procedure, the endoscopists found that the quality of this image was significantly superior to that of the standard image \( (p < 0.0001) \) (Fig. 4). The average quality score attributed to the FICE images was 9.39 (range 5–10). The mean difference between the standard image and the best FICE image was +2.02 \( (p < 0.0001) \). The differences also favored the second-best \( (+1.74, p < 0.0001) \) and third-best \( (+1.08, p < 0.0001) \) FICE images.

Quality of the pit pattern

The quality of the pit pattern was scored on a 10-cm scale. Although the endoscopists considered that pit-pattern quality was good on the standard images (mean score 7.08, range 2–10), there was a statistically significant difference compared with the quality of the pit pattern on the best FICE image \( (p < 0.0001, \text{mean } 9.43, \text{range } 6–10) \). The mean difference was +2.35 in favor of the best FICE image \( (p < 0.0001) \) (Fig. 5), and remained significant for the second-best \( (+2.16, p < 0.0001) \) and third-best \( (+1.56, p < 0.0001) \) FICE images.

Table 2 Computed virtual chromoendoscopy best five channels.

<table>
<thead>
<tr>
<th>Rank 1 (%)</th>
<th>Rank 2 (%)</th>
<th>Rank 3 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Channel 4</td>
<td>39.7</td>
<td>20.1</td>
</tr>
<tr>
<td>2 Channel 7</td>
<td>9.5</td>
<td>10.6</td>
</tr>
<tr>
<td>3 Channel 0</td>
<td>8.4</td>
<td>10.1</td>
</tr>
<tr>
<td>4 Channel 2</td>
<td>7.8</td>
<td>9.5</td>
</tr>
<tr>
<td>5 Channel 5</td>
<td>6.7</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Figure 4 Conventional endoscopic image (a) and virtual chromoendoscopy images (b, c) of normal gastric mucosa.

Images spontanée (a) et de chromoendoscopie virtuelle (b et c) de la muqueuse gastrique normale.
Distinction between pathological and normal mucosa

For the imaging of polyps, the junction between the pathological and normal mucosa was scored on a 10-cm scale. The endoscopists considered the quality of the junctional zone on the spontaneous images to be good (mean quality score 6.46, range 2—10), but there was a statistically significant difference in quality compared with the FICE images ($p < 0.005$, mean 8.82, range 3—10). The mean difference was +2.36 for the best FICE image, +2.01 for the second best FICE image and +1.52 for the third best FICE image.

Discussion

To our knowledge, this was the first prospective study assessing the quality of FICE virtual chromoendoscopy in upper gastrointestinal disease. The study findings enabled a comparison of technical qualities between the standard images and the images reconstructed by the FICE system.

Despite its usefulness for the detection of planar lesions, virtual chromoendoscopy is not widely used in routine practice. Yet, the virtual color technique has the advantage of enhancing surface analysis without using indigo carmine. For the endoscopist, indigo carmine staining is time-consuming, as a second exploration is then required after staining. In addition, it can be difficult to achieve uniform staining of the mucosal surface, and the technique does not allow vessel analysis [4,5]. With chromoendoscopy, however, the mucosa can be ‘stained’ virtually while examining a given area of mucosa. Furthermore, unlike the blue stain, the virtual technique offers a range of colors selected by the channel settings. A final advantage is the alternate use of virtual and standard images. In our study, we compared the virtual chromo images with the spontaneous images to obtain an objective assessment of the quality of the reconstructed images.

In Europe, upper endoscopy is generally performed with 200,000- to 400,000-pixel gastrosopes. The resolution of the images used in the present study was 1.3 million pixels. Despite this better resolution, the quality of the FICE images was still considered superior to that of the standard images obtained with a 1.3-million-pixel gastroscope ($p < 0.001$). Improved image quality favors detection of mucosal irregularities. The capillary architecture and the pit pattern are major endoscopic criteria of suspected dysplasia [4—7]. The FICE system is an important tool for the detection of difficult-to-recognize planar or depressed gastroduodenal lesions. Pohl et al. [4] evaluated the visibility of vessels using fibroscopic procedures in patients at risk of gastric cancer. Their study highlighted the simplicity of the FICE system in routine practice in comparison with indigo—carmine staining, but provided no information on the qualities of the technique in comparison to spontaneous images.

Our study enabled an assessment of the theoretical contribution of the FICE system. None of the six endoscopists had used the FICE system before this study. Our study highlighted the benefits of certain settings for exploration of the gastric cavity. Channel 4 was found to be the best setting, independently of the organ explored (stomach or duodenum), or the pathological or normal nature of the mucosal surface. Moreover, the three best settings (channels 4, 7 and 10) all provided images of far superior quality in comparison to the standard image, demonstrating the validity of diagnostic virtual chromoendoscopy.

This study also highlighted the usefulness of the FICE system for analysis of gastroduodenal lesions. The size
of sessile lesions may be underestimated with standard endoscopy. In our study, the quality of the analysis of the pathological—normal mucosal junction was also significantly better with virtual chromoendoscopy \((p < 0.0001)\). Using FICE before polypectomy would allow assessment of the junctional zone and, thus, enable complete resection. The superiority of the reconstructed image, and its easy use and instantaneous image analysis also offers enhanced detection of mucosal anomalies. Further studies will be necessary to collect more evidence of the expected benefits of the technique in terms of de novo detection, as illustrated by a few cases so far (Fig. 3).

**Conclusion**

Virtual chromoendoscopy contributes substantially to the analysis and description of endoscopic images. The quality of the instantaneously reconstructed image is superior to that of the spontaneous image. Among the 10 channels proposed for the FICE system, channel 4 provides significantly better image quality, for both normal and pathological mucosa.

The FICE system is a simple technological development that integrates well with the current gastroendoscopy systems. The tool provides major improvements in image quality and surface analysis. Evaluation of the junction between the pathological and normal mucosa is enhanced with virtual chromoendoscopy. For this reason, the technology can be used to assess gastric and duodenal polyps, and should enable better technical conditions for resection.

**Comment**

This study was conducted independently, with no support from Fujinon.

**References**