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Analysis of Electronic Endoscopic Image of Intramucosal Gastric Carcinoma Using Hemoglobin Index

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Abstract

It has been suggested that the endoscopic color of intramucosal gastric carcinoma is correlated with mucosal vascularity within the carcinomatous tissue. The development of electronic endoscopy has made it possible to quantitatively measure the mucosal hemoglobin volume, using a hemoglobin index. The aim of this study was to make a software program to calculate the hemoglobin index (IHb) and then investigate whether the mucosal IHb determined from the electronic endoscopic data is a useful marker for evaluating the color of intramucosal gastric carcinoma, in particular with regard to its value for discriminating between the histologic types. The mean values of IHb for the carcinoma (IHb-C) and the mean values of IHb for the surrounding non-cancerous mucosa (IHb-N) were calculated in 75 intestinal-type and 34 diffuse-type gastric carcinomas. Then, we analyzed the ratio of the IHb-C to IHb-N. The mean IHb-C/IHb-N ratio in the intestinal-type carcinoma group was higher than that in the diffuse-type carcinoma group (1.28±0.19 vs. 0.81±0.18, respectively, p <0.001). When the cut-off point of the C/N ratio was set at 1.00, the accuracy rate, the sensitivity, the specificity, and the positive and negative predictive values of a C/N ratio below 1.00 for the differential diagnosis of diffuse-type carcinoma from intestinal-type carcinoma were 94.5%, 94.1%, 94.7%, 88.9% and 97.3%, respectively. IHb is useful for quantitative measurement of the endoscopic color in intramucosal gastric carcinoma and the IHb-C/IHb-N ratio would be helpful in distinguishing diffuse-type carcinoma from intestinal-type carcinoma.

Key words : Gastric Carcinoma, Electronic Endoscopy, Hemoglobin Index, Image

1. Introduction

Mucosal color changes seen at endoscopy are important for gastrointestinal endoscopic diagnosis, not only because it enables the endoscopist to detect flat or depressed intramucosal gastric carcinomas which are usually small, but also because it helps to predict the degree of histologic differentiation of these cancers. The intestinal-type gastric carcinoma has the same color or reddening when compared with surrounding non-cancerous mucosa, whereas the diffuse-type gastric carcinoma is discolored and has a paler color compared with surrounding mucosa[1]. In some pathologic studies, these color changes seen endoscopically in intramucosal gastric carcinoma seemed to be correlated with the vascularity within the carcinomatous mucosa[2]. However, there have been few studies in which the vascularity of intramucosal gastric carcinoma was measured quantitatively in vivo[3].

Conventionally, the endoscopic color of early gastric carcinoma has been described as reddened, the same, discolored, or pale when compared with the color of the surrounding non-cancerous mucosa[1,2]. Such descriptions have been subjective, however, and it was not possible to measure color quantitatively.

Hemoglobin is the predominant pigment in the gastro-intestinal mucosa, so measurement of the hemoglobin content is a reasonable method for quantifying the color in the gastrointestinal endoscopic images. Recently, a technique for measuring mucosal hemoglobin content using electronic endoscopic imaging data have been developed[4]. This quantitative assessment has rarely been applied to the diagnosis of gastric cancer[3,5,6]. If the color changes seen endoscopically in intramucosal gastric carcinomas actually derive from the mucosal vascularity of the carcinomatous tissue, then it could be assumed that the measurement of mucosal hemoglobin content would be a useful marker for a quantitative assessment of the endoscopic color of gastric carcinoma.

If the IHb in the regions of interest of the endoscopic image is calculated automatically by a software program, it might be very helpful to measure color quantitatively. However, there is no software program to calculate the IHb in the regions of interest as long as we know.

Accordingly, the aim of this study was to make a software program to calculate the IHb and then investigate whether the mucosal hemoglobin index determined from the electronic

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endoscopic data is a useful marker for evaluating the color of intramucosal gastric carcinoma, in particular with regard to its value for discriminating between the histologic types.

2. Patients and Methods

2.1 Subjects

Electronic endoscopic images of 109 intramucosal gastric carcinomas from 109 patients were studied from January 2003 and May 2005. The patients had no anemia, congestive heart failure or portal hypertensive gastropathy. All carcinomas were of the superficial type (Type 0-II) according to the macroscopic classification of the Japanese Research Society of Gastric Cancer[7]. The 109 gastric carcinomas were divided into two groups according to Lauren's classification[8]: 75 intestinal-type and 34 diffuse-type.

The electronic endoscopic system consisted of an EVIS-240 and EVIS LUCERA videoscope system (Olympus Optical Co., Ltd., Tokyo, Japan) with a magnetic optical disk drive. An electronic upper endoscope such as GIF-Q240, GIF-Q260 or GIF-H260 (Olympus Optical Co., Ltd., Tokyo, Japan) was connected to the system and the white balance was readjusted for calibration of red, green, and blue signals prior to each examination. Any mucus on the gastric mucosa or on the lens was removed by careful washing with water before the endoscopic image was obtained. A directly facing view of the lesion was obtained after extension by insufflated air at a distance of 2 to 6 cm from the lesion[4,5]. The electronic endoscopic images were recorded in the database system without any compression or image processing, following analogue- to-digital conversion by 24-bit color image capture board during the endoscopic examination.

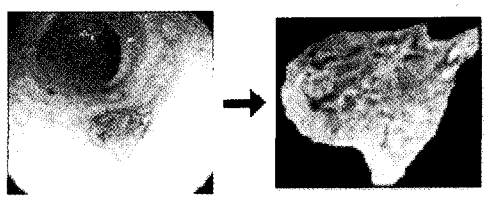
2.2 IHb measurement

IHb was calculated for each pixel of electronic endoscopic images by logarithmic transformation of the Vr/Vg ratio using the following equation: $IHb = 32[\log_2(Vr/Vg)]$ [4]. In the above equation, Vr indicates signal brightness for red (wavelength near 650 nm, showing minimal absorption by Hb) and Vg indicates signal brightness for green (wavelength near 560 nm, showing maximal absorption by Hb).

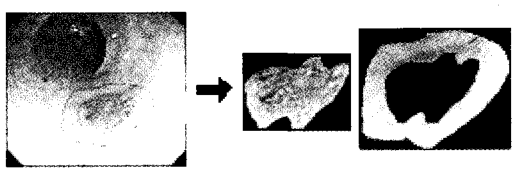
2.3 Software program for calculating the IHb

2.3.1 Area Selection

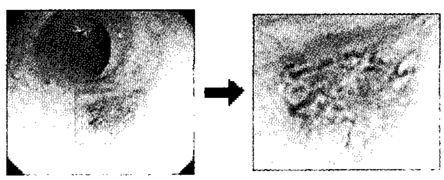
In the medical image processing, image areas being interested need to be selected from input images for the accurate and fast processing. Currently, methods of 4 types are used for the area selection, such as user-defined, doughnut-type, rectangle-type and line-type. In the user-defined selection method, users can draw the boundary of an area being interested using the moving mouse, so that the area being closest to a user-wanted one is able to be selected. The user-defined method displays the selected area by detecting and linearly connecting the mouse position per 1/100 second. So, a rugged and polygonal area is selected if users move fast the mouse, while a fine and detailed area may be selected if users move slowly the mouse. In the doughnut-type method, firstly, users draw an area of user-defined shape, and draw another one of a wanted shape in the inside or outside of the area, consequently generating two areas, the inner area and the doughnut-type area. The doughnut-type method is able to separately analyze the interested area and the surrounding area and support the comparison between two areas. In the rectangle-type method, if users mark the start point and the end point of an area being interested using the mouse, the rectangle area fitting the line between two points as a diagonal line is selected. In the line-type method, if users mark the start and the end points of a line being across the interested area, an area of belt-type including the line is displayed.



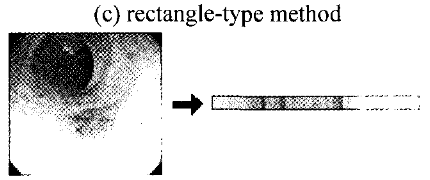
(a) User-defined method



(b) doughnut-type method



(c) rectangle-type method



(d) line-type method

Fig. 1 Examples of area selection methods

2.3.2 Analysis of Area and Line

For the analysis of a selected area, the analysis system is able to take shape for each color channel and display results of the statistical analysis such as histograms, mean values and median values for color channels, etc. Also, the system supports the area segmentation into smaller areas along with color channels.

Generally, a selected area is displayed using the RGB (Red, Green and Blue) color model in the computer, but the conversion into IHb color model is required for medical image analysis, because the distribution of Red color is able to be analyzed better on the IHb color model. Also, for the analysis of color distribution in a selected area, the color mean value R_{avg} and the color median value R_{mid} are calculated, and various information of color distribution for each color channel are displayed.

The distribution information for color channel is represented with histograms, mean values and median values for 3 channels of RGB color model and the IHb channel.

$$R_{avg} = \frac{1}{N} \sum_{x,y=0}^{n,m} \sum_{ch=r,g,b} R_{ch}(x,y) \qquad (1)$$

$$R_{avg} = \frac{1}{N} \sum_{x,y=0}^{n,m} R_{ihb}(x,y) \qquad (2)$$

$$R_{mid} = \frac{R_{high} - R_{low}}{2} \qquad (3)$$

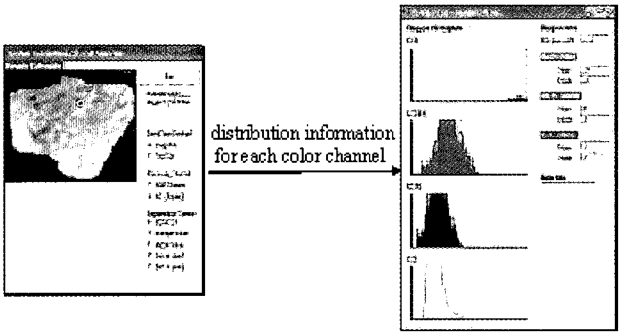


Fig. 2 Display example of the distribution information for each color channel in a selected area

The area segmentation function supported in the analysis system provides the picture-style representation of color distribution in a selected area by segmenting the area to smaller areas along with color channels. Also, the function can provide the information on the position of some color channel and the color value of a diagnostic area, etc.

	Segmentation on the RGB color model	Segmentation on the IHb color model

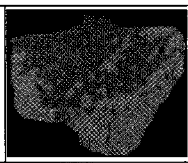
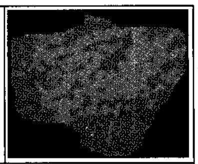
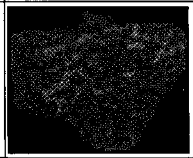
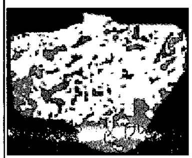
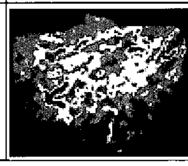
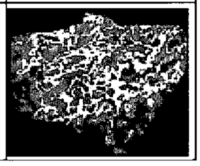
Segmentation using mean value		
Segmentation using median value		
Segmentation using user-defined value (RGB ch=135/ IHb ch=55)		
Segmentation using the user-defined number of segments (# of segments = 4)		
Segmentation proposed in this paper		

Fig. 3 Area segmentation results along with color models and segmentation methods

For the area segmentation function, some options such as the color model and the segmentation method are provided. In the color model option, the selection of IHb model is more efficient than RGB model for medical image analysis, and in the segmentation method option, one among the following methods can be selected: segmentation using mean value, segmentation using median value, segmentation using user-defined value and segmentation using the user-defined number of segments.

For the analysis of a predefined line, the analysis system displays the enlargement of the line and represents the color distribution of the line as histograms, mean values and standard deviations for color channels.

The enlargement of the line makes it possible the recognition by eye of the change of color values in the line to some level, and the histogram for each color channel depicts the change of color channel value along with the line in the whole. And the mean value L_{avg} and the standard deviation L_{deri} for each color channel are represented together the histogram, improving the ease of analysis.

$$L_{avg} = \frac{1}{n} \sum_{x=0}^{n} L_{ch}(x), \; ch = red, green, blue \qquad (3)$$

$$L_{deri} = \frac{1}{n}\sum_{x=0}^{n}\left|L(x) - L_{avg}\right| \quad (4)$$

The mean values of IHb for the carcinoma (IHb-C) and the mean values of IHb for the surrounding non-cancerous mucosa (IHb-N) were calculated in each of the regions of interest by using the software made by Lim EK and Kim KB. Then, we analyzed the ratio of the IHb-C to IHb-N.

3. Results

The mean C/N ratio in the intestinal-type carcinoma group was higher than that in the diffuse-type carcinoma group: 1.28±0.19 versus 0.81±0.18, respectively (p <0.001, Figure 4).

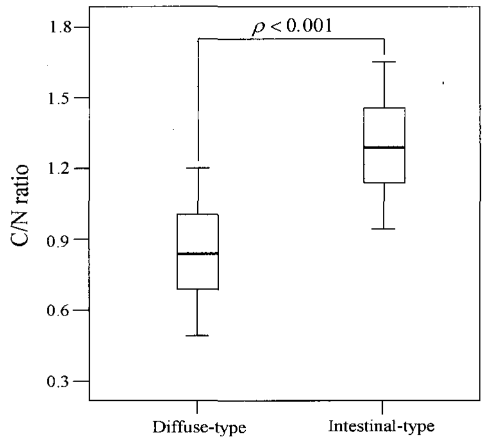


Fig. 4 C/N ratio in the diffuse-type carcinoma group and in the intestinal-type carcinoma group

The C/N ratio was in excess of 1.0 in 94.7% (71/75) of the intestinal-type carcinoma group (Table1). In contrast, the C/N ratio was below 1.0 in 94.1% (32/34) of the diffuse-type carcinoma group. Especially the C/N ratio was below 1.0 in all 13 diffuse-type carcinomas in the body.

Table 1: Results of C/N ratio in the intestinal-type group and in the diffuse-type group

C/N ratio \ type	Intestinal-type (n=75)	Diffuse-type (n=34)
<1.0	32	4
≥ 1.0	2	71

In this study, the measurement of the IHb calculated from electronic endoscopic imaging data was used to quantify the endoscopic color of gastric carcinoma. We showed that the intestinal-type carcinoma group had higher C/N ratio than the diffuse-type carcinoma group. Also we showed that the C/N ratio was in excess of 1.0 in 94.7% (71/75) of the intestinal-type carcinoma group and 5.9% (2/44) of the diffuse-type carcinoma group. These results was similar to the previous report[3] and this fact suggest that the C/N ratio by using IHb is of clinical relevance in distinguishing between intestinal-type carcinoma and diffuse-type carcinoma.

Although it is possible to suggest the histologic type of carcinoma by a simple description of the endoscopic color of lesion, it is very subjective. Recently, Yao et al. firstly reported an objective method for evaluating the endoscopic color of the early gastric cancer and for discriminating the histologic type of carcinoma by using the C/N ratio of IHb[3].

In the endoscopic diagnosis of small flat or depressed intramucosal gastric carcinoma, morphologic characteristics such as irregular and polygonal shape, clear demarcation, and irregular margins are important[9,10]. The diagnosis of depressed-type intramucosal gastric carcinoma is relatively easy on gross inspection through careful endoscopic assessment[10]. From the standpoint of a scientific approach to endoscopic diagnosis, we stress that an objective value (C/N ratio of IHb) for standardizing endoscopic color is highly superior to any subjective or descriptive expressions such as reddened, slightly reddened, the same or discolored compared with surrounding mucosa.

In previous pathologic studies, the vascularity of gastric carcinoma within the mucosa was shown to differ according to the degree of histologic differentiation[2,11,12]. It was found that the mucosal vascularity of differentiated carcinoma compared with surrounding non-cancerous mucosa was higher or about the same in most lesions, but lower in a few. However, the mucosal vascularity of most undifferentiated carcinomas was hypovascular compared with the surrounding non-cancerous mucosa. These differences in vascularity have been explained as being due to differences in the microvascular architecture of the carcinomatous tissue. Intramucosal differentiated carcinoma was often accompanied by a proliferation of vessels within the neoplastic interstitial tissue, while the individual carcinoma cells of intramucosal undifferentiated carcinoma infiltrated discretely and destroyed the normal mucosal vascular architecture without any proliferation of interstitial tissue. Consequently, differences in mucosal vascularity contribute to the endoscopic color change of intramucosal gastric cancer, that is, the reddened color of differentiated gastric carcinoma derives from increased mucosal vascularity, whereas the paler color of undifferentiated gastric carcinoma is due to reduced vascularity.

We showed that a C/N ratio of IHb below 1.00 had a high accuracy rate (94.5%) for diffuse-type intramucosal gastric carcinoma and this result was similar to the previous report[3]. This fact could be useful in the selection of patients who should not undergo endoscopic resection.

Our results was similar to the previous report[3]. But, there is a differentiation in the analyzing method between the study of Yao et al. and our study. They analyzed the linear region of the carcinoma and the surrounding non-cancerous mucosa but there is possibility of the defaults. First, the linear region of carcinoma is very small portion of carcinoma and doesn't represent the whole region of carcinoma. Second, the C/N ratio of IHb could be changed according to the selection of linear region. For example, if there is a flat carcinoma with focally reddish and focally whitish lesion, the C/N ratio of IHb may be increased when analyzing the reddish lesion but may be decreased when analyzing the whitish lesion.

4. Conclusions

In this study, we analyzed the area of the carcinoma and the surrounding mucosa. Because we included more region (the whole region in many cases), we could avoid the above defaults.

But we still have some limitation in analyzing the area of the carcinoma and surrounding mucosa. First, we couldn't sometimes include the whole area of the carcinoma in one endoscopic image due to large size or the problem of location. In this situation, we selected the region of interest. Second, the border of carcinoma that we marked could be somewhat different from the true border of carcinoma in some cases. But the different degree of between the marked border and true border of carcinoma is small, so it would not influence our results.

In conclusion, IHb is useful for quantitative measurement of the endoscopic color in intramucosal gastric carcinoma and the C/N ratio using IHb would be helpful in distinguishing diffuse-type carcinoma from intestinal-type carcinoma.

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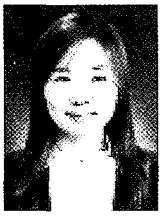

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