Contour Analysis of Endoscopic Images in the Diagnosis of Early Gastric Cancer

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Abstract

Purpose of the Study: The main purpose of the study is creation of a system for digital processing of endoscopic images in white light and narrow band imaging for the early diagnosis of early forms of stomach cancer.

Materials and Methods: The object of the study is endoscopic images (6320 cases) with PENTAX EG-2790K and OLYMPUS H180 devices. The subjects of the research are mathematical models of gastric epithelial neoplasia, classification of these tissues, methods of digital image processing and contour analysis, methods of mathematical modeling.

Results: The work is divided into two stages to obtain quantitative estimates of the studied characteristics:

1. To make a diagnostic map - the image is segmented, then the boundaries between the pathologically altered tissues and the normal mucous membrane are drawn.
2. The calculation of the characteristics of the contour associated with diagnostic signs is made.

As a measure of the symmetry of the figure, the symmetry coefficient k was used, defined as the ratio of the number of samples of the normalized autocorrelation function that exceeded the specified threshold in level to the total number of samples. The study revealed that the contours of malignant neoplasms have a symmetry coefficient \(k < 0.05\) and the contours of benign neoplasms \(k < 0.2\). This suggests the possibility of automated differentiation of neoplasms based on the analysis of their shape.

Conclusion: An objective assessment of endoscopic signs of early gastric cancer is necessary to standardize and systematize the diagnostic approach. The unified digital processing of endoscopic images will allow the endoscopist to increase the frequency of detecting early forms of gastric cancer, which will affect to reduce mortality.

Keywords: Early Gastric Cancer; Endoscopic Diagnostics; Symmetry Coefficient; Digital Image Processing

Introduction

Currently, in Russia, stomach cancer has the third place in the overall structure of oncological diseases [1]. Every year, about 38 thousand new cases are registered in the Russian Federation and more than 33 thousand cases lead to a lethal outcome. Men get sick 1.3 times...
more often than women; the peak of the morbidity occurs at the age of over 70 years [2]. Fortunately, over the past 50 years, the morbidity and mortality from stomach cancer has been decreasing, especially in economically developed countries.

There are many classifications of neoplasms of the gastrointestinal mucosa. For unification, the revised Vienna Classification of Gastrointestinal Epithelial Neoplasia was proposed in 1998 as an international consensus [3]. Among the neoplasms there are: without intraepithelial neoplasia, with questionable intraepithelial neoplasia, with low- and high-grade intraepithelial dysplasia, carcinoma with submucosal invasion. So, we determined a single indication for the endoscopic treatment of gastric cancer. Highly effective treatment improves the quality of patient’s life and increases lifespan.

The adoption of new technologies in endoscopy allows us to expand the diagnostic research’s possibilities and to increase their informativeness. Chromoendoscopy, narrow-spectrum diagnostics and endoscopy with magnification help to obtain additional information about suspicious areas of the mucous layer.

According to the recommendations of the Japanese Society of Endoscopy, the signs of early cancer are: a changing of the structure and a changing of the surface’s color of the gastric mucosa, a changing of the vascular pattern, an uneven edge of the lesion, an asymmetry of the lesion’s contours - called “Magic cross” [4]. However, the problems of objectification are not solved. For the complete accuracy it is necessary to solve the problem of quantitative assessment of the neoplasia, so we can standardize the diagnostic approach and differentiate between normal and pathological epithelium successfully.

The study of the lesion’s image in the monochrome spectrum has become available for digital processing. Contour analysis methods are used to obtain mathematical models of gastric epithelial neoplasia [5]. So, it became possible to perform quantitative processing of endoscopic images and to unify the diagnostic approach, which will ultimately reduce the death rate of stomach cancer.

**Methods**

This article presents an analysis of the endoscopic examination of 6320 patients. Each patient had an endoscopy procedure with white light and with a narrow spectrum. The criteria for the presence of a neoplastic process in the gastric mucosa were: a changing of the color and the surface, the presence of an irregular vascular pattern, the presence of the lesion boundaries and the asymmetry of the edge. Neoplasia was characterized according to the Paris classification: type I-elevated, type II-flat superficial, type III-depressive (ulcerative). For histological verification, a targeted biopsy of each the neoplasms were performed.

**Results and Discussion**

Figure 1-4 show endoscopic images of gastric mucosal neoplasia in different cases. The patient F., 59 years old, (white light image), there is a focus of local depression of the gastric mucosa with a well-defined border, irregular color, non-uniform surface and asymmetric contours. Morphological examination of the biopsy material (b) showed high grade dysplasia (Figure 1).
The patient G., 62 years old, white light image- (Figure 2a and 2b), there is polypoid neoplasia of the gastric mucosa with a non-uniform color and an uneven surface and an asymmetry border. A morphological examination showed a moderately differentiated adenocarcinoma (Figure 2c).

Figure 2: Early gastric cancer of the polypoid type (0-I), a, b - endoscopic photo, c-histological photo (moderately differentiated adenocarcinoma).

Figure 3 shows the pathological process in the antrum- the patient V., 64 years old. White light image- (Figure 3a), where a local depression of the mucous with clearly defined borders and a symmetrical edge was detected. An irregular vascular pattern with a clear asymmetric contour was seen in a narrow light spectrum. Histological examination (Figure 3b) confirmed the presence of highly differentiated adenocarcinoma.

Figure 3: Early gastric cancer of the superficial type (0-II), a - endoscopic photo, b - histological photo (well-differentiated adenocarcinoma).

Figure 4 shows a neoplasia with ulceration. Asymmetric borders with a non-uniform surface color and irregular vascular pattern present. Histological examination showed a low differentiated adenocarcinoma.

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In order to obtain objective quantitative estimates used for the diagnosis of early gastric cancer, methods based on contour analysis of images can be used. Contour analysis is a set of methods for selecting, describing, transforming image contours, and recognizing of the images. The contour contains the necessary information for verifying images by their appearance [5].

**Outcomes**

The results of the diagnosis of early gastric cancer and the comparison of indices from the total number of studies (6320) both without using digital processing and with using digital processing are presented on a figure 5.

**Figure 4:** Early gastric cancer of the ulcerative type (0-III): a - endoscopic photo, b - histological photo (poorly differentiated adenocarcinoma).

**Figure 5:** Comparative results of early gastric cancer diagnostics without digital image processing and with digital image processing (The total number of examined, the number of examined without digital image processing and with digital image processing).
To obtain quantitative assessments of the signs, the work is divided into two stages:

1. To form a diagnostic map, the image is segmented, then the edges between the pathologically changed tissues and the normal mucous layer are drawn.

2. The contour characteristics associated with diagnostic signs are estimated.

To solve the first problem, it is necessary to test the statistical hypothesis that the image fragments belong to one general population using the t-criterion or the Fisher, but the variation series preserves more complete information about the sample. It only lacks data on the ordering of the marks in the strobe. Since the brightness distribution is random, the information about the order of the samples in the sample does not matter.

To segment the image and highlight the fragments corresponding to neoplasia, a small fragment of the neoplasm is allocated, and a reference variation series is formed on its basis. A second strobe is triggered throughout the image, the dimensions of which are the same as the first one. At each position of the gate, the current variation series is formed and the degree of difference between the reference and current variation series is determined by the standard deviation criterion.

Pixels for which the probability value is less than the limit are considered to belong to a locally homogeneous region. When processing color images, this procedure is performed for three channels: red, green, and blue. The results are combined between each other [5,6].

After selecting the neoplasia's contour, it is necessary to perform a quantitative assessment of the signs. So, it is necessary to calculate the degree of the neoplasia's symmetry, which contains complete information about the image's contour. The symmetry of the shape is determined by the degree of self-similarity under various geometric transformations. Shapes that do not have pronounced metric properties will have only one pronounced peak. In this regard, as a measure of the symmetry of the figure, it is proposed to use the symmetry coefficient $k$, defined as the ratio of the number of samples of the normalized autocorrelation function that exceeded a given threshold in terms of the total number of samples. For a circle, this indicator will be equal to 1, for a cross, $k = 0.153$ at a threshold level of 0.8, for a contour of a neoplasm, $k = 0.028$.

Figure 6-10 show examples of processing various images of neoplasms and the results of figuring the symmetry coefficient ($k$).
Contour Analysis of Endoscopic Images in the Diagnosis of Early Gastric Cancer

Figure 7: Image processing (early gastric cancer) $k = 0.027$.

Figure 8: Image processing (benign neoplasm) $k = 0.232$.

Figure 9: Image processing (benign neoplasm) $k = 0.292$.

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From the results obtained, the contours of malignant neoplasms have a coefficient of symmetry $k < 0.05$ and the contours of benign neoplasms have a coefficient of symmetry $k > 0.2$. This allows us to draw a conclusion about the possibility of differentiation of neoplasms based on the results of the analysis of their shape.

**Conclusion**

An objective analysis of endoscopic images for early diagnosis of the gastric’s epithelial neoplasms is necessary and involves a quantitative description of pathological focuses. Contour image’s analysis of gastric’s neoplasms obtained by endoscopy with monochrome light, identification of the asymmetry of the neoplasm’s contours with further digital processing, determination of the symmetry coefficient contributes to the quantitative assessment of pathological focuses and to the detection of early gastric cancer. It is known that stomach cancer at the early stages has a low risk of metastasis, so we are able to treat the patients at this stage and reduce mortality rates and increase the lifespan.

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