Textural characteristics of bone marrow blast nucleus images with different variants of acute lymphoblastic leukemia

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Abstract. The paper describes the method of recognition of T- and B- variants of acute lymphoblastic leukemia in microscopic images of blood cells. The method is based on the use of texture characteristics of images. Experimental recognition accuracy evaluation is obtained from the sample of 38 patients (17 with T-ALL and 21 with B-ALL variants of acute lymphoblastic leukemia). The obtained results show the possibility of applying the proposed approach to the differential diagnosis of T- and B- variants of acute lymphoblastic leukemia.

1. Introduction.
Diagnosis of acute lymphoblastic leukemia (ALL) and their variants is based on integrated morphocytochemical and immunophenotypic study of blasts in bone marrow aspirate [1, 2]. The study of cells in stained preparations includes evaluation of their various parameters: size, shape, and characteristics of the nuclei chromatin structure: thin netting, lumpy or dense. Blasts nuclei structure polymorphism is associated with a variety of immunophenotypical features, due to their belonging to different lines of hemopoiesis of B- or T-direction. Morphological heterogeneity of blast population is noted at T- and B- variants of ALL. Attempts of identifying of a logical relationship between the chromatin structure of blasts nuclei and immunophenotypic status has failed to date. Computer microscopy with using a multispectral camera has more wide opportunities to study the structure of nuclear chromatin fibres than optical microscopy. It allows you to objectify the data obtained in the form of numerical indices. Digital expression of the results of the study provides detailed analysis of the peculiarities of the blasts nuclei structure images in preparations of bone marrow of patients with B- and T- ALL [3-8].

The aim of this work is the comparative evaluation of texture characteristics of nuclei chromatin of bone marrow blasts with T- and B- variants of ALL. Wavelet transformation and spatial adjacency matrix were used for texture characteristics calculations.

2. Materials and methods
The sample of preparations of 38 patients was formed. 17 of them had T-ALL and 21 patients had B-ALL. The diagnosis was revealed on using morphocytochemical and immunophenotypic studies,
which were carried out in the laboratory of immunology of hematopoiesis of N. N. Blokhin Russian Cancer Science Center (head of the laboratory MD. Professor N. N. Tupitsyn).

The automated microscope Olympus BX43 with the Imperx camera IPX-4M1ST-GCFB was used for shooting digital images.

4930 images of bone marrow lymphoblasts were obtained for the study. There were 2048 lymphoblasts images from bone marrow preparations of patients with T-ALL and 2882 lymphoblasts images from bone marrow preparations of patients with B-ALL. Textural and wavelet features of blasts nuclei were calculated for the obtained images. Color model RGB, XYZ, HSL, Lab, Luv, LCH, HLS, HSV, YUV, YIQ, YCbCr, CMY were used for computation [9-13]. The areas with a size of 45x45 pixels inside blasts nuclei were selected for analyze. 513 types of textural characteristics for each of the cells were calculated. Then the characteristics averages for the cells sample in the preparations of each of patients were calculated.

The ALL type recognition was carried out using a linear classifier with a distance function Euclidean, Manhattan and Chebyshev in two-dimensional feature space [8]. We used all possible pairs of averages for all 513 textural characteristics types.

Table 1. Generalized characteristics $M_{\text{ENT}}$ and $M_{\text{RENGE}}^{-1}$ for the group of T- and B-cells of ALL patients

| The patient (type of blasts) | Quantity of cells | $M_{\text{ENT}}$ | $M_{\text{RENGE}}^{-1}$ | The patient (type of blasts) | Quantity of cells | $M_{\text{ENT}}$ | $M_{\text{RENGE}}^{-1}$ |
|-----------------------------|------------------|-----------------|---------------------|-----------------------------|------------------|-----------------|---------------------|
| P 1(B)                      | 159              | 5,778           | 72,501              | P 20(B)                     | 181              | 5,824           | 68,640              |
| P 2(B)                      | 176              | 5,373           | 66,157              | P 21(B)                     | 193              | 6,104           | 69,871              |
| P 3(B)                      | 166              | 5,798           | 71,040              | P 22(T)                     | 82               | 5,904           | 78,917              |
| P 4(B)                      | 103              | 5,664           | 69,700              | P 23(T)                     | 154              | 5,527           | 69,256              |
| P 5(B)                      | 100              | 5,874           | 72,396              | P 24(T)                     | 100              | 5,574           | 70,021              |
| P 6(B)                      | 183              | 5,887           | 73,818              | P 25(T)                     | 121              | 5,784           | 73,764              |
| P 7(B)                      | 146              | 5,730           | 66,776              | P 26(T)                     | 83               | 5,791           | 74,632              |
| P 8(B)                      | 170              | 6,055           | 72,907              | P 27(T)                     | 130              | 5,740           | 75,390              |
| P 9(B)                      | 117              | 6,120           | 70,409              | P 28(T)                     | 131              | 6,176           | 77,764              |
| P 10(B)                     | 116              | 5,898           | 72,213              | P 29(T)                     | 124              | 5,518           | 75,200              |
| P 11(B)                     | 107              | 5,640           | 68,775              | P 30(T)                     | 172              | 5,683           | 75,799              |
| P 12(B)                     | 33               | 5,867           | 77,986              | P 31(T)                     | 76               | 5,895           | 75,241              |
| P 13(B)                     | 168              | 6,097           | 71,219              | P 32(T)                     | 37               | 5,619           | 73,221              |
| P 14(B)                     | 51               | 5,921           | 71,565              | P 33(T)                     | 153              | 5,357           | 70,243              |
| P 15(B)                     | 115              | 5,954           | 74,195              | P 34(T)                     | 181              | 5,701           | 80,181              |
| P 16(B)                     | 73               | 6,007           | 73,637              | P 35(T)                     | 113              | 5,542           | 71,888              |
| P 17(B)                     | 185              | 5,798           | 65,043              | P 36(T)                     | 124              | 5,701           | 73,003              |
| P 18(B)                     | 214              | 5,607           | 66,611              | P 37(T)                     | 128              | 5,656           | 71,110              |
| P 19(B)                     | 126              | 5,637           | 67,796              | P 38(T)                     | 139              | 5,274           | 67,594              |

3. Results

$M_{\text{ENT}}$ and $M_{\text{RENGE}}^{-1}$ were identified as a couple of signs, in which the ALL variants detection occurred with minimal error. M represents the average value for the blast cells of the patient preparation. Index "ENT" corresponds to the texture characteristic entropy, calculated for R (red) coordinate in the RGB color space. The index "RENGE^{-1}" corresponds to the value of wavelet characteristic "relative range" for U (color-difference) component in the YUV color space. The data obtained are presented in Table 1. A graphical representation of Table 1 is shown in figure 1.
Thus, on these characteristics, you can judge the ALL variant (T - or B - type). Using of these characteristics allowed to achieve 95% recognition accuracy of ALL variants (T - or B – type).

Generalized criterion $C_{GC}$ was proposed for the practical evaluation of the ALL type. The value of this criterion is calculated according to the formula: $C_{GC} = M_{ENT} \cdot 0.998 + M_{RENGE} \cdot (-0.065)$.

$C_{GC}$ criterion distribution histogram for two classes of patients with ALL T-type and B-type is presented in figure 2.

Using a criterion value $C_{GC} = 1.405$, you can diagnose variant of acute lymphoblastic leukemia according to the rule: if $C_{GC} > 1.405$, then B-ALL type is, if $C_{GC} \leq 1.405$, then T-ALL type is [14].

Thus, a study based on computer analysis of images of the nuclear chromatin structure showed effective application of the apparatus of the texture analysis for establishing the T- and B- variants of acute lymphoblastic leukemia.
4. Conclusion
The study showed that the use of the texture analysis method of the blood cells nuclei images on microscopic examination of bone marrow aspirates allows to distinguish T- and B-variants of acute lymphoblastic leukemia. In experimental studies were used bone marrow aspirates preparations from 17 patients with T-ALL and 21 patients with B-ALL.

In further experiments we plan to increase the volume of the preparations sample. In addition, research will be conducted to establish correlations between morphological and immunophenotypical characteristics of lymphoblasts L1, L2, L3 types, pre-B, pre-pre-B, Pro-B and pre-T types for the differential diagnosis of appropriate modifications of acute leukemia with the use of computer microscopy.

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