Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/bbe

Review Article

Peripheral blood smear analysis using image processing approach for diagnostic purposes: A review

Roopa B. Hegde [a], Keerthana Prasad [a,*], Harishchandra Hebbar [a], I. Sandhya [b]

[a] School of Information Sciences, Manipal University, Manipal 576104, India
[b] Department of Pathology, A J Institute of Medical Sciences and Research Center, Kuntikana, Mangalore 575004, India

ARTICLE INFO

Article history:
Received 23 November 2017
Received in revised form
19 January 2018
Accepted 2 March 2018
Available online xxx

Keywords:
Peripheral blood smear
Image analysis
Computer aided diagnosis
Malaria diagnosis
Leukemia diagnosis

ABSTRACT

Peripheral blood smear analysis is a common practice to evaluate health status of a person. Many disorders such as malaria, anemia, leukemia, thrombocytopenia, sickle cell anemia etc., can be diagnosed by evaluating blood cells. Many groups have reported methods to automate blood smear analysis for detection of specific disorders for diagnostic purposes. In this paper, we have summarized the methods used to analyze peripheral blood smears using image processing techniques. We have categorized these methods into three groups based on approaches such as WBC analysis, RBC analysis and platelet analysis. We conclude that there is a need for a method of automation to match with human evaluation process and rule out any abnormality present in the blood smear. It is desirable for studies on automation of peripheral blood smear analysis to focus on development of robust method to handle illumination and color shade variations. Also, it is desirable to design a method which could collect all the abnormal regions from all views of a specimen to limit the manual evaluation to those regions making it more feasible for telemedicine applications.

1. Introduction

Peripheral blood smear (PBS) analysis is a routine work carried out in laboratories to evaluate the health status of a person. Microscopic evaluation is used to find the cause of the disease and thus provides a suitable treatment to the affected individual [1]. The analysis starts from collection of blood sample, preparation of peripheral blood smear and evaluation of blood cells under a microscope [2]. The peripheral blood comprises of three types of cells namely white blood cells (WBCs), red blood cells (RBCs) and platelets. WBCs can be of five different types namely neutrophil, eosinophil, basophil, lymphocyte and monocyte. Fig. 1 shows RBCs, types of WBCs and platelets. They vary in size, shape, color and texture. Variations of these features and the

* Corresponding author at: School of Information Sciences, Manipal University, Manipal 576104, India.
E-mail addresses: roopabhegde@gmail.com (R.B. Hegde), keerthana.prasad@manipal.edu (K. Prasad), harish.hebbar@manipal.edu (H. Hebbar), drsandhyai@yahoo.co.in (I. Sandhya).
https://doi.org/10.1016/j.bbe.2018.03.002

Please cite this article in press as: Hegde RB, et al. Peripheral blood smear analysis using image processing approach for diagnostic purposes: A review. Biocybern Biomed Eng (2018), https://doi.org/10.1016/j.bbe.2018.03.002

number of occurrence of cells are observed and recorded in laboratories [1].

Manual approach of pathologists for evaluation of blood smear is summarized in Table 1. They look for size and distribution of RBCs followed by maturity of WBCs, its cytoplasmic changes and intensity of nucleus, and platelets for their count and appearance [2]. Manual microscopic examination consists of two types of analysis namely quantitative and qualitative analysis. Quantitative analysis is counting of blood cells. This includes two types of counting methods namely complete blood count (CBC) and differential count (DC). CBC provides total counts of WBCs, RBCs and platelets whereas DC provides counts of each type of WBCs in the peripheral blood. Automatic cell counters can be used for CBC which counts the number of cells based on indirect parameters such as density or impedance of cells, but morphological analysis is mostly performed manually. Both qualitative and quantitative analysis play a vital role in diagnosis of many diseases. Irregularities in the count or appearance of blood cells indicate abnormal condition. Anemia, sickle cell anemia, malaria, hemolytic syndrome, polycythemia are some of the diseases caused by RBC disorders. Appearance of RBCs in malaria and shape based disorders are shown in Fig. 2. WBC abnormality is observed in case of neutropenia, neutrophila, eosinophilia, basophilia, leukemia, lymphoma, HIV, parasitic and fungal infections. Leukemia is the only disease which is usually diagnosed through PBS analysis [4]. Fig. 3 shows the various appearances of abnormal WBCs. Disorders related to platelets are myeloproliferative disorders and thrombocytopenia. Liver disease, kidney disease and hypothyroidism are also diagnosed using blood smear analysis [5]. During manual evaluation, pathologists place the slide with blood smear under the microscope and observe all the components of blood. They look for shape, size, color, texture and count of RBCs, WBC, and platelets. The step by step approach taken by a pathologist for manual evaluation of blood smear is summarized in Table 1. Any deviation from the expected normal appearance of each of the blood components is considered as an abnormal condition and appropriate further evaluation is carried out to reach a conclusion on the diagnosis. For example, even while the pathologist starts checking a smear for malaria infection, he/she follows the steps listed in Table 1 and does not only check if the RBCs are infected with malaria parasites, he/she identifies any other abnormalities too if present. Hence, an automated system for diagnostic purposes must be designed to match with human evaluation process in order to identify abnormal cases appropriately.

The evaluation results may vary among labs. It depends on skill and experience of the technician, instruments and methods used to analyze the blood sample. Manual microscopic examination is time consuming and results show poor repeatability [7]. American Medical Association (AMA) has reported that 41.5 million complete blood count and differential count tests were conducted in the year 2015 [8]. Many researchers tried to bring automation in evaluation of blood cells using image processing, as a decision support system. Image processing has become one of the common visualization and interpretation methods in medicine over the past few decades [9]. The main objective of image analysis is to gather information to detect and diagnose the disease quickly. Image processing facilitates automation in the system and also provides objective results.

In this paper we provide a review of various attempts for automation of diagnosis based on peripheral blood smears using image processing. We also report our observations on the research gaps and conclude with our suggestions for future work.

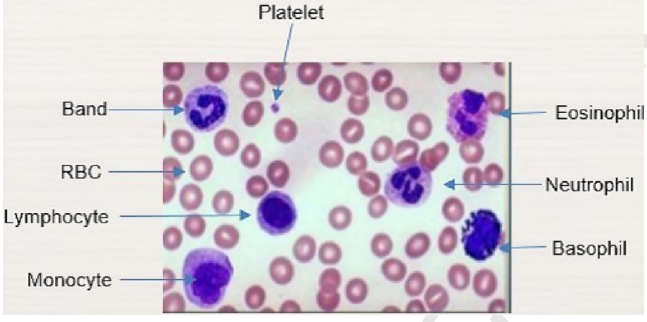

Fig. 1 – Peripheral blood smear image [3].

Table 1 – Pathologists approach for manual evaluation.

Cell type	Observations
RBCs	Compare size with small lymphocytes, uniform distribution, central pallor area 1/3 of total size, any inclusions, shape, size
WBCs	Looking for mature WBCs, total count and differential count, Nucleus to cytoplasm ratio, cytoplasmic changes, presence of granules, intensity of nucleus, nuclear lobulation, based on which immature cells and blast are categorized
Platelets	Count, size, clumps

2. Approaches

Various research groups worked on different aspects of automation of peripheral blood smears for diagnostic purposes. The approaches of categorized automation of peripheral blood smear analysis is as follows.

Group 1: WBC analysis

(a) Identification and counting of WBCs
(b) Identification of types of normal WBCs
(c) Classification of WBCs into normal and leukemia

Group 2: RBC analysis

(a) Identification and counting of RBCs
(b) Identification and classification of malaria
(c) Identification and classification of sickle cell anemia
(d) Identification and classification of other RBC disorders

Group 3: Platelet analysis

There are three types of blood cells namely WBCs, RBCs and platelets. Hence we categorized the state-of-the-art methods into three groups namely WBC analysis (Group 1), RBC analysis

Please cite this article in press as: Hegde RB, et al. Peripheral blood smear analysis using image processing approach for diagnostic purposes: A review. Biocybern Biomed Eng (2018), https://doi.org/10.1016/j.bbe.2018.03.002