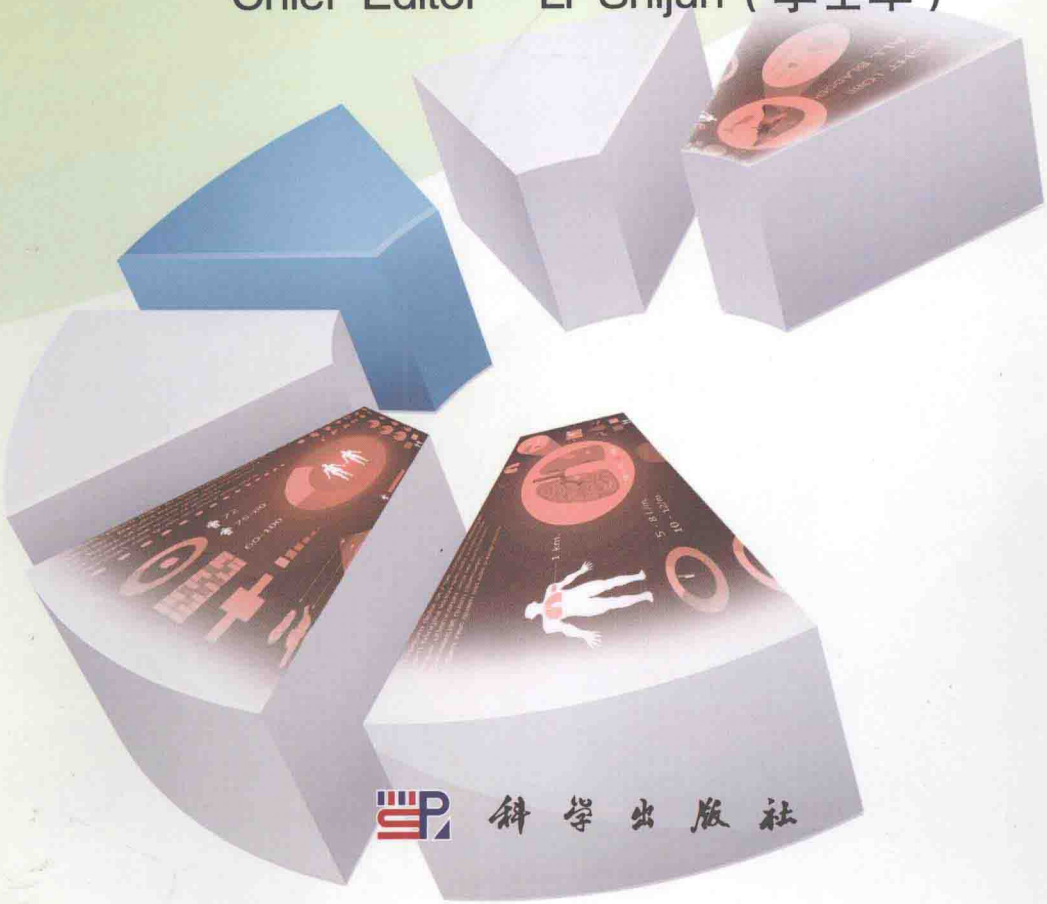
中国科学院教材建设专家委员会规划教材
全国高等医药院校规划教材

LABORATORY DIAGNOSTICS

实验诊断学

（英文版）

Chief Editor Li Shijun（李士军）



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内 容 简 介

本书针对实验诊断学教学中的难点和重点，根据临床对实验诊断的需求，深入浅出地介绍了临床血液、体液检验、骨髓检验、血栓与止血、临床生化检验、临床免疫检验、临床微生物及分子生物学检验。书中参考了国内外最新进展，对临床常用的检验项目的特性及临床应用评价作了详细的阐述，希望对临床医师及检验人员有更多的参考价值。

本书内容精练、科学，实用性强，可作为高等医学院校留学生、研究生、七(八)年制、本科生教材使用，也可供临床医师及科研人员参考。

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Preface

With rapid development of laboratory diagnostics, it played more and more important role in clinical diagnosis. Being as an important branch of diagnostics, it serves as a bridge between preclinical medicine and clinical medicine. Laboratory diagnostics is a subject that can scientifically utilize laboratory results for clinical diagnosis, differential diagnosis, monitoring pathogenetic condition, observing curative effects and prognosis.

Clinical laboratory detects the samples such as blood, body liquid, secretions, excreta and cast-off cells in vitro by reagent, apparatus and technology. It can take quality control broadly and achieve reliable results of data. According to the above results or data, corresponding to clinical information and other auxiliary examinations, laboratory diagnosis analyses logically and scientifically. Ultimately, it can provide objective evidence for diagnosis, research and health care. Recently, with the development of the preclinical medicine, clinical medicine and bioengineering, etc. Clinical laboratory is making progress to high theory, high technology and high level. As a result, it forms laboratory medicine gradually.

Laboratory diagnosis mainly includes clinical hematology diagnosis, clinical chemistry diagnosis, clinical immunology diagnosis, clinical microbiology diagnosis and clinical molecular biology diagnosis.

Today, laboratory diagnostics has been updated continuously with the development of some corresponding subjects and laboratory technology, such as automatic apparatus, reagent diversification, methodology standardization,consummation of quality assurance system, clinical application of molecular biology, growth of evidence based laboratory medicine and emergence of point of care test. All of the developments can improve and enrich laboratory diagnosis.

It is my great honor to be in charged of compiling this book. But by finishing it hurriedly, I think there are some mistakes undoubtedly. I hope they can be found by the students and my colleagues and can be corrected in the next edition. Valuable suggestions are also necessary and welcomed.

I hope you will find this book a useful tool. Good luck!

Li Shijun, Dalian
2014-7

Contents

Chapter 1 General introduction

Section 1 Laboratory diagnostics introduction

Besides the physical diagnosis and imaging diagnosis, laboratory diagnostics makes an important contribution to the diagnosis of diseases. With rapid development of laboratory diagnostics, it plays more and more significant role in clinical diagnosis, serving as an important bridge between basic medicine and clinical medicine.

1.1.1 Concept of laboratory diagnostics

Laboratory diagnosis refers to using specimens collected from human's body (include blood, body fluid, secretion and excrement), select suitable reagent, instrument analysis, quality control, system management, and then get the accurate results. The results are provided to physicians and other healthcare professionals with informations as follows:

(1) Disease diagnosis.

(2) Differential diagnosis.

(3) Guide for treatment and monitor efficacy of therapy.

(4) Prognosis assessment.

(5) Prevention of disease.

(6) Conduct scientific research.

(7) Health status evaluation and early warning of high-risk condition.

Therefore, laboratory diagnostics is a compulsory and key course for clinical medical students, and contains the basic knowledge and skills for clinician. Through systemic learning, medical students should master the diagnostic methods, make full use of the information and improve the diagnostic ability.

1.1.2 Contents of laboratory diagnostics

1. Clinical hematology and body fluids examination Clinical hematology consists of some tests including: complete blood count, hemolysis tests, bone marrow examination, hemostasis and thrombosis examination, hemorheology, blood type examination and cross-matching, etc. The routine examinations of body fluid include the tests of urine, feces, semen and prostatic fluid, vaginal discharge, cerebrospinal fluid, and serous cavity fluid, etc.

2. Clinical chemistry Clinical chemistry includes the examinations about body's physiological components, metabolism function and biochemical function of important organs (such as liver, kidney, heart, etc.), and drug concentration monitoring and toxicological analysis. It contains examination of electrolytes, enzyme, protein, glucose, lipid, hormone and acid-base balance, etc.

3. Clinical immunology It includes evaluation of immune system function, autoimmune disease examinations, clinical serological examinations, tumor markers examinations, etc.

4. Clinical microbiology In order to detect the infectious diseases, nosocomial infection, and sexually transmitted diseases, pathogens tests are made by the methods of bacteria smear, culture and identity analysis, drug sensitive test in vitro, and pathogen serology test, etc.

1.1.3 Characteristics of laboratory diagnostics

Laboratory examinations have undergone revolutionary changes over the past decades, more than 80% of the clinical inspection items are detected by automatic instruments, such as automatic blood cell analyzer, automatic urine analyzer, automatic biochemical analyzer, etc. The clinical laboratories have already formed a series of automated clinical inspection systems, with the characteristics of high accuracy and precision, multi-parameter, advanced intelligence, high throughput and speed.

According to different testing project, clinical laboratory can choose the reagents produced by different manufacturers. Ideal testing methods require international standardization. It is important that the sensitivity and accuracy of the testing methods must comform to the best level.

Usually, clinical laboratory technicians use scientific methods and management measures, such as internal quality control (IQC) and external quality assessment (EQA) to evaluate the experimental tests, including sensitivity, specificity, positive predictive value, negative predictive value, etc. These methods ensure the veracity and reliability of the experimental results effectively.

Section 2 Laboratory diagnostics standardization

Laboratory diagnosis provides the objective results for the clinical decision. With the development of biochemistry, molecular biology, immunology and hematology, the diagnostic techniques and methods are constantly under standardization, which directly regulate the subject much more objective and scientific than ever. In order to standardize the clinical experiments, many factors should be considered. The factors include specimen collection, transport and storage, physical influence factors, reagent and instruments, etc.

1.2.1 Specimen collection, transport and storage

Examination results are affected by many factors, including specimen collection, transport, storage, inspection methods, instruments, reagents, personnel quality, etc. The physiological state of the patients also affects test results.

1. Specimen collection

(1) Blood specimen types: The specimen types contain.

1) Whole blood: It is used for clinical hematology examination, complete blood count, cytological classification, and morphology inspection.

2) Serum: It is light yellow transparent liquid after natural coagulation of blood in vitro. The fibrin has been removed, and it is mainly used for clinical chemical and immunological analysis.

3) Plasma: After mixed with anticoagulant and centrifugal precipitation, the upper layer yellow liquid was isolated, which contains fibrinogen and blood coagulation factor, can be used for chemical, hemostasis and thrombosis analysis.

Different purpose should select different blood specimen.

(2) Requirements of blood sampling

1) Classification of blood samples: capillary blood is suitable for infants and the burned

patients, mainly used for point of care test (POCT) or emergency test. Venous blood is the most commonly used,usually select elbow vein, wrist vein, hand vein, and even external jugular vein for infants. Arterial blood is used for blood gas analysis, usually select the femoral artery and brachial artery.

2) Sampling time

Fasting blood samples: Usually in the morning before breakfast, patients should keep at least 8 hours fasting till collecting blood. This type of blood commonly used in chemical tests. The advantage is that it can avoid the interference of diet and physiological activities.

A special time of blood samples: Some blood components change along with the physiological cycle, such as hormone and glucose, etc.

Random blood samples: Usually used for emergency patients.

(3) Addition of anticoagulants

1) Ethylenediaminotetraacetate(EDTA): The anticoagulant mechanism of EDTA is to chelate with calcium ion , mainly used for hematology cell counts , cell morphology examination, ABO type and Rh type detection, antibody screening, etc.

2) Heparin: It can strengthen the anticoagulant effect of antithrombin. Heparinized plasma is used for osmotic fragility test of RBC, blood gas analysis, clinical chemical examination,etc.

3) Citrate (as sodium salt) in 3.8%: The mixture consists 1 part sodium citrate and 9 parts whole blood, mainly used for hemostasis and thrombosis examination. For the erythrocyte sedimentation reaction (ESR), 1 part sodium citrate and 4 parts whole blood are collected in the syringe.

4) Fluoride (as sodium salt): This activity results in the inhibition of both coagulation and glycolysis and it is used for blood glucose determination.

(4) Urine and other body fluids collection requirements: See details in the corresponding chapters.

2. Specimen transport and preparation The samples must be transported in an immediate manner after collection. The separation of serum or plasma from the whole blood should be finished within 2 hours since collection. Serum and plasma must be inspected whether there are hemolysis, lipemia, and bilirubinemia, which can interfere with test results.

3. Specimen storage Serum or heparinized plasma for the determination of enzymes and substrates can maintain stable for one week at 4-8℃. Platelet-poor citrated plasma for hemostatic and thrombus exmination can maintain stable less than 8 hours at room temperature. EDTA blood for the determination of complete blood count (without a differential count, but including a platelet count) can maintain stable for 24 hours at room temperature. Isolated serum for detection of serum proteins, including immunoglobulins, and specific antibodies, tumor markers can storage for up to 1 week at 4-8℃.

Long-term storage: storage temperature lower than −20℃ is required, sharp-freezing is important for maintaining the structure of proteins. The process of thawing must occur very slowly, either overnight at 4-8℃ or in a water bath under constant agitation. The sample must be well mixed prior to analysis.

1.2.2 Physiology influence factors

In preparing a patient for phlebotomy, we should take care of them to minimize factors which are related to activities that might influence laboratory results. The factors include diurnal variation,exercise, fasting, diet, ethanol consumption, tobacco smoking, drug ingestion, and posture.

1. Diurnal variation It may be encountered when testing for hormones, iron, acid phosphatase, and urinary excretion of most electrolytes such as sodium, potassium and phosphorus.

2. Exercise Calcium, phosphorus, potassium, sodium, transaminase, urea, uric acid, bilirubin will be doubled after exercise. Therefore, before blood is collected, the patient should have a rest and avoid strenuous exercise.

3. Gender Quite a lot of laboratory tests (such as GGT, triglycerides, uric acid, creatinine, ammonia, CK, AST, ALP, iron, urea, cholesterol,etc) can change widely according to different gender.

4. Race Racial differences are important in the frequency distribution of blood group determinants.

5. Age Some elements (blood glucose, urea, cholesterol, LD activity, etc) increase with the increasing of age while others (calcium, phosphate, total protein, albumin, etc) decrease. In comparison to adults, higher enzyme activities are found during childhood, whereas iron, copper, and immunoglobulins have a lower concentration.

6. Alcohol A few minutes after the intake of alcohol, AST rises mildly and 3 hours later can reach the maximum which usually falls within the reference interval of non-drinkers. After a time delay, there is a slight rise in GGT. The influence on other enzyme activities is hardly measurable.

7. Tobacco Long term smoking can increase Hb, RBC, leukocyte counts, insulin, epinephrine and growth hormone. Smoking also affects the body's immune response. IgA, IgG and IgM are lower in smokers while IgE levels are higher. Comparing with non-smokers, research has shown that sperm counts and motility decrease while the ratio of abnormal morphology increase.

8. Posture An upright position increases hydrostatic pressure, causes a reduction of plasma volume and increases the concentration of analyte, such as albumin, total protein, enzymes, calcium,bilirubin, cholesterol, triglycerides, and drugs bound to proteins.

9. Pregnancy Under the pregnancy, some indices such as ALP, cholesterol, triglycerides, copper, ceruloplasmin, transferrin, leukocyte count, progesterone, estradiol, estriol, prolactin will rise. HCG and alpha-fetoprotein can be found under the pregnancy. On the contrary, iron, magnesium, calcium, total protein, albumin, cholinesterase, hemoglobin, HCT and RBC count will decrease.

1.2.3 Standardization of methods

Laboratories must assess the reliability of experimental methods, understand the methodology performance of inspection.

1. Precision It is the reproducibility of the measurements and the prerequisite for accurate, but high precision is not necessarily guarantee high accuracy. It contains within batch precision

and inter-batch precision.

2. Accuracy It is the close degree between observation value and true value, mainly affected by systematic errors.

3. Sensitivity It describes the ability of a method to differentiate between values adjacent to each other. It indicates to what extent a value changes depending on the signal of the system to be measured. The sensitivity can be quantified by the slope of the calibration line.

4. Specificity It is the ability of a method to detect only the analyte under consideration. Other components of the samples should not influence the analytical result.

1.2.4 Reagent and instrument

The technicians are responsible for the management of instrument, should establish instrument archives, standard operating procedures, using records, regular maintenance, instrument calibration, and verification procedures records, and make the instrument to meet the requireements of standards.

Experimental reagents should be managed by special technicians. All reagents should be used within the period of validity. If batch number is changed, technicians need to carry on the comparison experiment.

1.2.5 Personnel quality

It is important for an operator to have enough basic theoretical knowledge, skilled technique, developing thinking, rigorous spirit, noble medical ethics for providing credible results to clinical departments and research.

Section 3 Quality system (QS)

The purpose of quality control is to find out mistakes in the process of analysis, control and analyze each link of testing process, prevent from sending out the unreliable results.

Quality control in laboratories includes the following three aspects: pre-analysis, analysis and post-analysis phase. To ensure the quality of laboratory work, technicians must implement the total quality management (TQM).The goal is to manage experiment process and service in a continuous and comprehensive way, monitor each testing links and meet clinical requirements.

1.3.1 Pre-analysis of quality control

Pre-analysis phase refers to all the activities that take place prior to testing, such as test ordering, patient's preparation, sample collection and transport to clinical laboratory. It is mainly controlled by clinical doctors and nurses. Pre-analysis of quality control is the basis of total quality management. According to statistics data, dissatisfied test results in the clinical are mostly caused by unqualified specimen.

1.3.2 Analysis of quality control

Analysis of quality control includes specimen processing, assay determination, internal quality control (IQC), and external quality assessment (EQA).

1. Specimen processing After receiving samples, laboratory personnel check the quality

of specimen carefully. If unqualified specimen is found,laboratory personnel should contact doctor or nurse to collect sample again.

2. Assay determination It mainly contains detecting methods, reagent and instrument, etc.

3. Internal quality control (IQC) Laboratory staffs adopt certain methods and procedures to ensure the quality control continuously. It includes recording the measured value on quality control chart, assessing whether inspection quality within the expected range by a set of limit of detection or control rules. The purpose is to control the laboratory precision, evaluate the reliability of laboratory works.

4. External quality assessment (EQA) The quality control center will prepare and distribute the quality control samples to laboratories which take part in the EQA activity. Laboratories will detect the samples, send their results to the quality control center and then receive the feedback from the center. Using the standardized method that can trace the center, provide the accurate determination results According to this, center can compare the results from laboratories all over the country with the accurate one which is detect by itself and give the feedback to laboratories. If the results are unqualified, laboratory must seek for the reasons and correct the tests which are out of control.

1.3.3 Post-analytical of quality control

Post-analytical phase mainly contains data processing and abnormal test results reviewing. It also contains clinical evaluation of test results and clinical information feedback. Automatic analyzer and laboratory information system (LIS) are used in laboratories in recent years. Inspection results can be automatically processed to ensure the reliability of analysis results.

In order to provide an accurate and reliable test results, reduce and eliminate discrepancies, clinical laboratories should set up quality management system, establish the quality policy and quality objectives, perfect quality management system to control the main factors including technology, principle, staff, etc. At present, the clinical laboratories may apply for international laboratory accredition of ISO15189, ISO17025, for implementing the total quality management.

(Li Shijun, Duan Mengxi)

Chapter 2 Routine hematological examination

Section 1 Blood routine examination

Blood transports oxygen and nutrients to cells and tissues and at the same time removes waste materials and carbon dioxide. In addition, it plays a vital role in our immune system and in maintaining a relatively constant body temperature. The visible components of blood include white blood cells (WBC), red blood cells (RBC) and platelets.

Blood routine examination mainly includes blood cell counts, hemoglobin concentration examination, sometimes also includes erythrocyte sedimentation rate.

2.1.1 Red blood cell examination

1. Introduction Red blood cells (RBC) are the most common type of blood cells, the primary function of RBC is to carry oxygen from the lungs to body tissues and to transfer carbon dioxide from the tissues to the lungs. The cytoplasm of erythrocytes is rich in hemoglobin, an iron-containing biomolecule that can bind oxygen and is responsible for the red color of the cells. Approximately 2.4 million new red blood cells are produced per second. Red blood cells develop in the bone marrow and circulate for about 100-120 days in the peripheral blood before their components are recycled by macrophages.

2. Red cell count and hemoglobin concentration RBC count is to evaluate the number of red blood cells per liter blood, together with the hemoglobin concentration is used to screen for diseases associated with anemia, determine the severity of anemia and observe the response to treatment for anemia.

(1) Reference interval: See Table 2-1.

Table 2-1 Reference interval of RBC count and Hb concentration

	RBC count	Hb concentration
Adults male	$(4.0\text{-}5.5)\times10^{12}$/L	120-160g/L
Adults female	$(3.5\text{-}5.0)\times10^{12}$/L	110-150 g /L
Neonate	$(6.0\text{-}7.0)\times10^{12}$/L	170-200g/L

(2) Clinical significance: Increase in RBC and Hb concentration: RBC count $>6.0\times10^{12}$/L, Hb concentration> 170g/L in adult males or RBC count $>5.5\times10^{12}$/L, Hb concentration> 160g/L in adult females.

1) Physiological conditions associated with increased RBC and Hb concentration. ①At high altitudes: Less atmospheric weight pushes air into the lungs, which causes hypoxia and a decrease pressure of oxygen. Increasing red blood cell production occurs in order to compensate for the low oxygen levels and inadequate tissue oxygenation. ②Strenuous physical training increases muscle demand for oxygen and increases release of RBC from bone marrow. ③Smokers also have a higher number of red blood cells than non-smokers.

2) Pathological conditions associated with increased RBC and Hb concentration. ①Polycythemia vera(PV) is a disease of unknown origin that results in an abnormal increase in

red blood cells. ②Pulmonary disease: Decreased respiratory function resulting in reduced oxygen concentration, the body tries to compensate by producing more red blood cells. ③Congenital heart disease: With this condition, the heart can not pump blood efficiently, resulting in a decreased amount of oxygen transporting to tissues. The body tries to compensate by producing more red blood cells. ④Kidney tumors produce excess erythropoietin which is used to stimulate a production of red blood cells from the bone marrow. ⑤Genetic causes alter oxygen sensing or affect releasing oxygen from hemoglobin. ⑥Dehydration: As the plasma volume of blood drops, the count of RBCs relatively increases,such as severe diarrhea and vomiting, diabetes insipidus and diabetic ketoacidosis.

Decrease in RBC and Hb concentration:According to the level of Hb, anemia can be classified as mild anemia (Hb 90-110g/L), medium anemia (Hb 60-90g/L), severe anemia (Hb 30-60g/L) and extreme severe anemia (Hb<30g/L).

1) Physiological conditions associated with decreased RBC and Hb concentration. ①Age: Reduction of red bone marrow in elder leads to physiological anemia. ②Pregnancy: Normally during pregnancy, erythroid hyperplasia of the marrow occurs, and RBC mass increases. However, the volume of plasma increases in a disproportionate then can cause hemodilution. Therefore RBC and Hb concentration in blood decrease relatively.

2) Pathological conditions for a decrease: decrease of RBC and HB concentration may be caused by reduced RBC production or increased RBC destruction.

Reduced RBC production:①Bone marrow disorders:Hypoproliferation of bone marrow (e.g, aplastic anemia), hematological malignancy (e.g, leukemia, lymphoma, and myelomas) cause the production of RBC decrease.②Bone marrow damage: Toxin, radiation or chemotherapy, infection and drugs inhibit hemopoietic function of bone marrow. ③Nutritional deficiency: Iron is necessary for the normal productions of hemoglobin, however Vitamin B_{12} works together with folate is important for the synthesis of DNA of red blood cells.④Deficient erythropoietin(EPO): Erythropoietin is used to stimulate an adequate production of red blood cells from the bone marrow. EPO deficiency can be found in severe and chronic kidney diseases or dialysis.

Increased RBC destruction: ①The production of abnormal red blood cells caused by intrinsic or extrinsic reasons can be eliminated by mononuclear phagocyte system.②Acute or chronic bleeding can cause the number of RBC and the hemoglobin concentration decrease.

3. RBC morphology evaluation The typical morphology of normal RBC is biconcave disc with the diameter of 6-9 μm. The color of cytoplasm is pink. Figure 2-1 shows the morphology of RBCs.

(1) Normal RBC: Normal mature RBC are biconcave, round discs that are about 6-9 μm in diameter.

(2) Abnormalities in size: ① Microcyte: diameter of the cell less than 6 μm and the center olistherozone disappear. Microcytes increase in hereditary spherocytosis(HS). ② Macrocyte: diameter of the cell more than 10μm. Macrocyte can be found in the following diseases : folate and B_{12} deficiencies anemia, hemolytic anemia, acute bleeding, liver disease, etc.③ Megalocyte: diameter of the cell more than 15μm. Megalocyte can be found in folate and B_{12} defici-

encies anemia.

(3) Abnormalities in hemoglobin content: ①Hypochromia: excessive central pallor >1/3 of its diameter in the erythrocyte. It is due to insufficient hemoglobinization. Hypochromia can be found in IDA, thalassaemia; sideroblastic anemia, etc. ②Polychromatic erythrocyte: Erythrocyte stains blue-gray as a consequence of uptake of both eosin (by hemoglobin) and basic dyes (by residual ribosomal RNA), often slightly larger than normal red cells and round in shape. It can be found in bleeding or hemolysis.

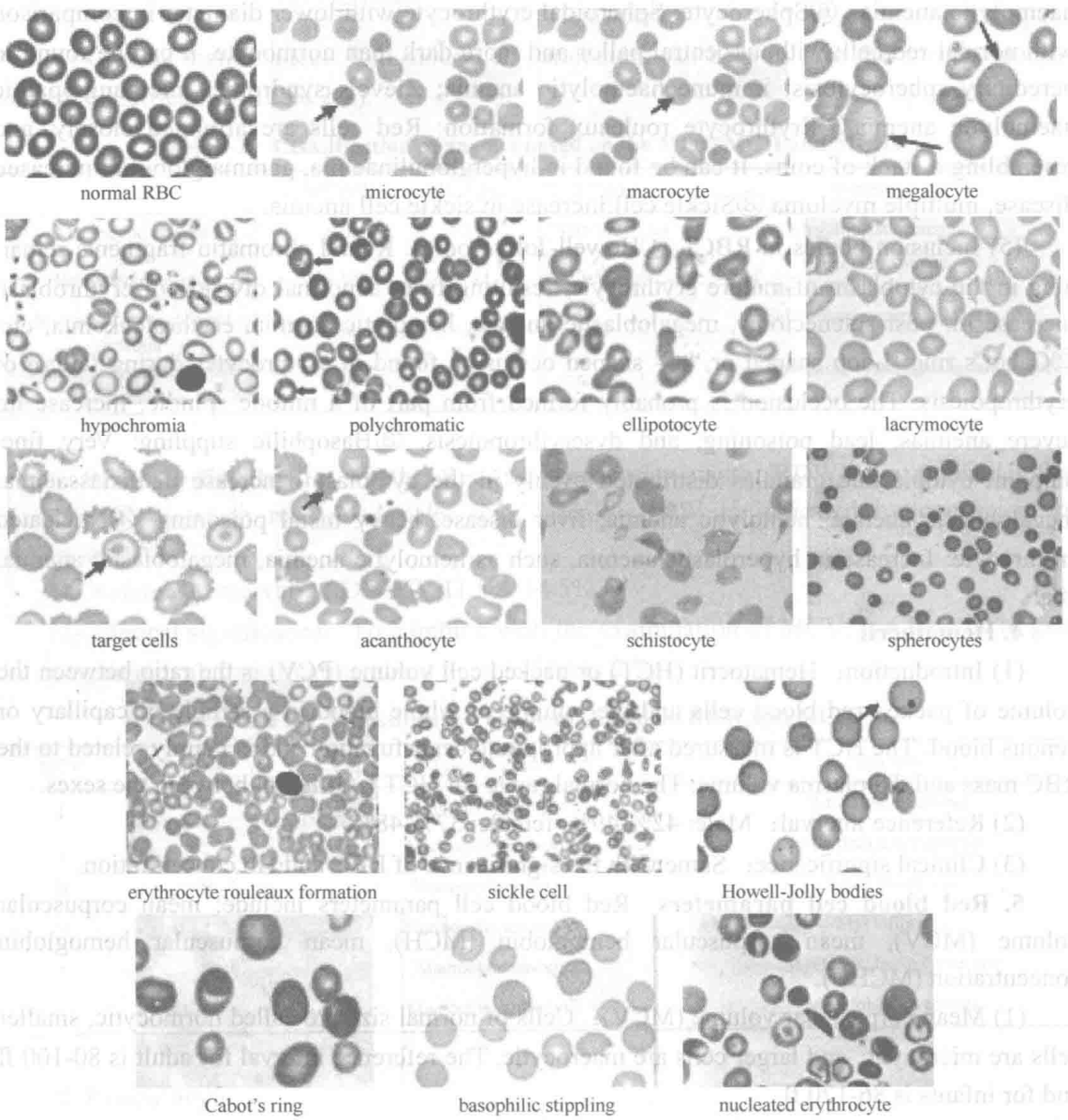

Figure 2-1 shows the morphology of RBCs

(4) Abnormalities in shape: ①Ellipotocyte: it appears oval or elongated. It can be found in hereditary elliptocytosis, megaloblastic anemia, IDA, thalassaemia, myelofibrosis. ②Tear drop cells: the shape of RBC looks like tear-drop. It can be found in bone marrow fibrosis, megaloblastic anemia, IDA, thalassaemia. ③Target cell: Erythrocyte containing dark stained

central area surrounded by lightly stained ring of cytoplasm without hemoglobin. It can be found in obstructive liver disease, severe iron deficiency, thalassaemia, haemoglobinopathies (S and C), post-splenectomy. ④Acanthocyte: Erythrocytes with irregular, long, sharply pointed and bent spicules of cytoplasm. It can be found in liver disease, post splenectomy, anorexia nervosa and starvation. ⑤Schistocyte: It is a fragmented part of erytrocytes. The typically shape is irregular , jagged, and have two pointed ends. A true schistocyte does not have central pallor. It can be found in DIC, micro angiopathic haemolytic anemia, mechanical haemolytic anemia. ⑥Spherocyte: Spheroidal erythrocyte with lower diameter in comparison with normal red cell; without central pallor and more dark than normocyte. It can be found in hereditary spherocytosis; immune haemolytic anemia; Zieve's syndrome; microangiopathic haemolytic anemia.⑦Erythrocyte rouleaux formation: Red cells are arranged closely, and resembling a stack of coins. It can be found in hyperglobulinaemia, gamma globulin increased disease, multiple myeloma.⑧Sickle cell:increase in sickle cell anemia.

(5) Inclusion bodies in RBC: ①Howell-Jolly bodies: Round chromatin fragments remaining in the cytoplasm of mature erythrocyte, resulting from abnormal division of erythroblast. Increase in: post splenectomy, megaloblastic anemia, hemolytic anemia, erythroleukemia, etc. ②Cabot's ring: Loop shaped or "8"- shaped occlusion found in erythrocytes during failure of erythropoiesis. The occlusion is probably formed from part of a mitotic spindle. Increase in: severe anemias, lead poisoning, and dyserythropoiesis. ③Basophilic stippling: Very fine, pinpoint cytoplasmic granules distributed evenly in the cytoplasm. Increase in thalassaemia, megaloblastic anemia, hemolytic anemia, liver disease, heavy metal poisoning. ④Nucleated erythrocyte: Increase in hyperplastic anemia, such as hemolytic anemia, megaloblastic anemia, et al.

4. Hematocrit

(1) Introduction: Hematocrit (HCT) or packed cell volume (PCV) is the ratio between the volume of packed red blood cells and the volume of whole blood in a sample of capillary or venous blood. The HCT is measured after appropriate centrifugation and is mainly related to the RBC mass and the plasma volume. The normal range for HCT is different between the sexes.

(2) Reference interval: Male: 42%-49%, female: 37%-48%.

(3) Clinical significance: Same with the significance of RBC and Hb concentration.

5. Red blood cell parameters Red blood cell parameters include: mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC).

(1) Mean corpuscular volume (MCV): Cells of normal size are called normocytic, smaller cells are microcytic, and larger cells are macrocytic. The reference interval for adult is 80-100 fl and for infants is 86-120 fl.

$$\text{MCV (fl)} = \frac{\text{Hematocrit}}{\text{Number of RBCs per liter}}$$

(2) Mean corpuscular hemoglobin (MCH): The reference interval for adult is 27-34 pg and for infants is 27-36 pg.