Editor's note: This publication is an updated version of an issue of The Veterinary CE Advisor that appeared in 1995, which was titled “Clinical pathology for small animal practitioners: Interpreting the hemogram.”

The complete blood count (CBC), serum chemistry profile, and urinalysis are the cornerstones of clinical laboratory assessment. It is important to perform all the tests concurrently on presentation, particularly in sick patients. Interpreting one test or one group of tests without the others is prone to diagnostic errors.

It is not our intention to provide veterinarians with every interpretation for every test in this article. Our goal is to help small-animal practitioners develop a systematic approach that enables them to logically evaluate hematologic data in any clinical situation.

Indications for hematology
A CBC provides a broad overview of a patient’s general health. For this reason, hematology is a critical component of laboratory evaluation of patients. The peripheral blood serves as the transport medium between the bone marrow and the tissues; consequently, a CBC provides a snapshot of the hematopoietic system at a specific point in time.

A CBC should be performed in every sick patient, every patient with vague signs of disease, and every patient undergoing a wellness or geriatric profile. A CBC is also indicated as a recheck test in patients with previous erythrocyte, leukocyte, or thrombocyte abnormalities and in conjunction with treatment involving medications that may affect erythrocyte, leukocyte, or thrombocyte lines, such as chemotherapeutics.

Sample collection and management
To ensure accurate hematologic interpretation, minimize artifacts as much as possible. Poor blood collection techniques, inadequate sample volumes, prolonged sample storage, and delayed sample analysis all provide opportunities for artifact formation.

Proper blood collection techniques help prevent erroneous results from sample clotting. To help ensure accuracy, obtain hematologic samples from the largest blood vessel possible, which will minimize cellular trauma and prevent activation of clotting mechanisms, and retest patients with clotted samples. Common venipuncture sites in dogs and cats include the jugular and cephalic veins and the lateral saphenous vein as it crosses the tarsus. Anticoagulants used in hematology include ethylenediaminetetraacetic acid (EDTA), heparin, and citrate. EDTA is the anticoagulant of choice for blood film preparation because it preserves cellular detail better than other anticoagulants.

Inadequate sample volume is a common cause of inaccurate hematology results. Completely filling anticoagulated blood collection tubes avoids a falsely decreased packed cell volume (PCV) and falsely decreased cell counts and prevents red blood cell (RBC) shrinkage.

Analyzing hematologic samples as soon as possible prevents artifacts created by exposure to anticoagulants and from cell deterioration due to storage and shipment. Examine samples within three hours of collection or refrigerate them at 39 F (4 C) to avoid artificially increased PCV and mean cell volume and decreased mean cell hemoglobin concentration.

Erythrocyte crenation, neutrophil hypersegmentation, and lymphocytic nuclear distortion may occur in aged samples, as well as monocytce vacuolization, monocyte...
pseudopod formation, and platelet aggregation. To prevent these morphological artifacts from occurring, prepare blood films within one hour of collection. In addition, keep formalin and formalin-containing containers away from all blood and cytologic smears to prevent inadequate staining.

**Blood film preparation and examination**

Examining blood films provides vital information for practitioners. Proper preparation and staining and systematic examination are necessary to interpret blood films accurately.

Producing high-quality blood films begins with clean, new slides; used slides frequently contain scratches and other physical imperfections. Slides must be free of fingerprints, dust, alcohol, detergents, and debris. Using a microhematocrit tube, place a small drop (2 to 3 mm in diameter) of well-mixed EDTA blood approximately 1 to 1.5 cm from the end of the sample slide. Next, draw a spreader slide back into the blood drop at approximately a 30-degree angle until the spreader slide's edge touches the sample drop and capillary action disperses the sample along the edge. Then use a smooth and steady motion to push the spreader slide away from the blood drop, creating a uniform film that covers nearly the entire length of the slide. Note that changing the angle of the spreader slide will change the length and thickness of the blood film. Allow the blood film to air-dry thoroughly before staining, and do not heat it. A high-quality blood film should have three distinct zones: the thick layer, the monolayer, and the feathered edge.

Most veterinary practices use Diff-Quik (Dade Behring) stain, which is a modified Wright's stain. Diff-Quik stain uses three separate solutions: an alcohol fixative (light blue in color), an eosinophilic staining solution (orange), and methylene blue stain (dark blue). To help ensure reliable results, use two separate Coplin stain jar sets—one for staining hematologic and cytologic samples and one for staining contaminated samples, such as ear and fecal cytologic specimens. Replace Diff-Quik stains routinely for optimal results. To properly stain the sample, dip the air-dried slide five to 10 times in each solution while blotting one edge briefly in between each solution. Rinse the slide with distilled water after the final staining step with the methylene blue, and allow the stained blood film to air-dry before examination.

A high-quality microscope is essential for hematology and cytology. We recommend a binocular microscope with 10×, 20×, 50× or 60×, and 100× oil immersion objectives. The microscope manufacturer will include cleaning instructions and maintenance information.

Systematic blood film evaluation includes assessment of all three zones of the film. In the monolayer—the zone between the thick layer where the blood drop originated and the much thinner feathered edge—the cells are individualized and do not overlap. This monolayer is the only area where evaluation of cell morphology should take place.

First, examine the blood film at low magnification (10× or 20×) and scan the entire slide to determine overall film thickness, cell distribution, and differentiation of the three layers. Examine the feathered edge for the presence of microfilariae, phagocytosed organisms, atypical cells, and platelet aggregation. Then, still using low magnification, evaluate the monolayer. Estimate the total white blood cell (WBC) count (see below) and predict the expected WBC differential count. Finally, use oil immersion (100×) to examine erythrocyte, leukocyte, and platelet morphology. Evaluate RBCs for evidence of anisocytosis, poikilocytosis, polychromasia, hemoglobin concentration, and RBC parasites. Important erythrocyte morphologic abnormalities include spherocytes, schistocytes, acanthocytes, and burr cells, among others. Examine leukocytes for important information—neutrophils for toxic change and the presence or absence of a left shift (elevated band neutrophils), lymphocytes for reactivity, and monocytes for phagocytosed organisms.

**Determination of cell counts**

Several technologies have been applied to determine erythrocyte, leukocyte, and thrombocyte counts in veterinary medicine. Traditional in-clinic hematologic evaluation methods include estimations from blood films, manual counting, electronic resistance (impedance) counters, and quantitative buffy coat analysis. Most reference laboratories use impedance technology or laser flow cytometry.

Making accurate cell count estimations directly from blood films requires experience. One method of estimating total leukocyte counts involves counting several 20× objective fields—10 to 20 WBCs per 20× field is considered normal in dogs and cats. Another method is to count several 100× oil immersion fields, then multiply the average number of WBCs per 100× oil immersion field by 2,000 to obtain a final estimated total WBC count. Determining total erythrocyte numbers from blood films is not recommended because variations in film thickness make counts imprecise.

Manual cell counting requires a counting chamber (hemacytometer) and close visual inspection. Although this method is inexpensive, it is labor-intensive and requires operator training and experience for successful analysis. Studies report a margin of error of 20% to 25% compared with automated methods.1

Electronic (impedance) counters use the Coulter principle developed in 1945. In this system, a suspension of blood cells in a metered volume of electrolyte medium
flows through a small orifice where a constant electrical current is applied. In theory, each cell emits an electrical signal unique to its classification, which the device registers and records. Disadvantages of impedance technology include a great deal of analyzer maintenance and cleaning, grouping of granulocytes together, and an inability to provide valuable reticulocyte information. In addition, platelet clumping frequently results in an artifactually increased total WBC count and decreased platelet counts because impedance counters often register clumped platelets as leukocytes.

Quantitative buffy coat technology incorporates cellular density and nuclear and cytoplasmic staining characteristics to discriminate cellular types. Advantages of this technique include ease of use, low maintenance, system abnormality alerts, a reticulocyte percentage report, and a visual buffy coat graph to aid in interpretation. Disadvantages include the inability to recognize feline eosinophils and the grouping of lymphocytes and monocytes together. Furthermore, the operator must understand the buffy coat graph to maximize the system’s usefulness.

Laser flow cytometry uses optical laser scattering to distinguish cellular elements. Advantages of this technology include a full five-part WBC differential (neutrophils, eosinophils, basophils, lymphocytes, and monocytes) plus expanded RBC information (reticulocyte percentage and absolute reticulocyte count) and platelet data (platelet volume and count). The disadvantage is the higher cost associated with this more sophisticated technology.

**Table 1**

<table>
<thead>
<tr>
<th>General patterns of leukocyte response</th>
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<tr>
<td>Inflammation</td>
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<tr>
<td>Acute</td>
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<tr>
<td>Total WBC count</td>
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<tr>
<td>Increased</td>
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<td>Segmented neutrophils</td>
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<td>Band neutrophils</td>
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<td>Increased</td>
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<tr>
<td>Lymphocytes</td>
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<tr>
<td>Decreased or no change</td>
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<tr>
<td>Monocytes</td>
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<tr>
<td>Variable</td>
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<td>Eosinophils</td>
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<td>Variable</td>
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<td>Chronic</td>
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<td>Increased or no change</td>
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<td>Variable</td>
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<td>Variable</td>
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<td>Overwhelming</td>
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<td>Decreased or no change</td>
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<td>Variable</td>
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<tr>
<td>Excitement leukocytosis</td>
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<td>Increased</td>
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<td>Increased in dogs; increased or no change in cats</td>
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<td>No change</td>
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<td>No change</td>
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<td>Stress leukogram</td>
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<td>Increased</td>
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<td>Increased</td>
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<td>No change</td>
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<td>Increased or no change</td>
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**Hemogram interpretation**

A CBC is composed of WBC, RBC, and platelet data as well as total protein concentration. In general, we prefer to evaluate WBC data first, RBC and protein data collectively next, and platelet data last. This order is useful because changes in WBCs often predict alterations in other hemogram findings.

**Evaluating the WBCs (leukogram)**

Leukogram data include total and differential WBC counts and a description of WBC morphology from the peripheral blood film. Differential cell counts should always be expressed and interpreted in absolute numbers, not percentages. All leukocyte compartments—including neutrophils and their precursors, eosinophils, basophils, monocytes, and lymphocytes—must be counted.

WBC data are used to answer the following questions:
1. Is there evidence of inflammation?
2. Is there evidence of a glucocorticoid (stress) or epinephrine (excitement) response?
3. Is there a demand for phagocytosis or evidence of tissue necrosis?
4. If inflammation is present, can it be further classified as acute, chronic, or overwhelming?
5. Is there evidence of systemic toxemia?

Table 1 lists the general patterns of leukocyte response under a variety of circumstances.

**1. Is there evidence of inflammation?** Neutrophilic left shifts (Figure 1), persistent eosinophilia, and monocytosis (Figure 2) are the best indicators of inflammation. Left shifts (increased numbers of immature, or band, neutrophils in circulation) indicate increased turnover and tissue use of neutrophils. Persistent peripheral eosinophilia indicates a systemic allergic or hypersensitivity reaction. Monocytosis is seen in peripheral blood when there is a demand for phagocytosis.

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Inflammatory leukograms without any of the above changes are possible, but they are harder to recognize. For example, a mild leukocytosis with mature neutrophilia may indicate inflammation, but it may also represent a physiological response to an epinephrine surge (excitation leukocytosis) or a response to endogenous or exogenous glucocorticoids. When the results of a leukogram are ambiguous, they can sometimes be clarified by repeating the CBC after several hours or days or testing for other markers of inflammation, such as erythrocyte sedimentation rates, fibrinogen concentrations, or reactive C-protein concentrations. A period of four hours is generally required to see important changes in the leukogram.

2. Is there evidence of a glucocorticoid (stress) or epinephrine (excitement) response? High concentrations of circulating glucocorticoids cause a mild mature neutrophilia, lymphopenia and eosinopenia, and mild monocytosis. Of these changes, lymphopenia is the most consistent and reliable indicator of stress. We regard lymphocyte counts of 1,000 to 1,500/µl as marginal lymphopenia, whereas lymphocyte counts below 1,000/µl are absolute lymphopenias. Stress typically results in lymphopenias in the range of 750 to 1,500 lymphocytes/µl. When lymphocyte counts drop below 600/µl, we consider other causes of lymphopenia, such as chyloous effusions, lymphangiec-tasia, and malignant lymphoma.

The presence or absence of a glucocorticoid response in the leukogram carries important implications for the interpretation of other laboratory data. High concentrations of circulating glucocorticoids can be associated with mild to moderate hyperglycemia in dogs (elevations that do not exceed the renal threshold), marked hyperglycemia in cats, and elevations in serum alanine transaminase (ALT) and serum alkaline phosphatase (ALP) activities in dogs. In particular, stress lymphopenias can be important in interpreting hepatic disorders. As a guideline, a greater than fourfold rise in serum ALP activity in a dog results either from cholestasis or high concentrations of circulating glucocorticoids. If lymphopenia is present, neither cause can be eliminated; if lymphopenia is absent, cholestatic liver disease is likely.

It’s important to distinguish the stress response accompanied by an increased concentration of circulating glucocorticoids from the excitement response associated with increased concentrations of epinephrine. The stress response is the result of changes both in circulating and bone marrow pools of leukocytes; it takes several hours to develop and persists for about 24 hours.

In contrast, with the excitement response, increased blood flow mobilizes marginating leukocytes from vessel walls and brings them back into circulation. This type of response dissipates in minutes. In dogs, excitement leukocytosis is primarily a mild mature neutrophilia; in cats, it is a lymphocytosis, a neutrophilia, or both.

3. Is there a demand for phagocytosis or evidence of tissue necrosis? Monocytosis indicates a demand for phagocytosis or tissue necrosis. Monocytosis is almost always present in chronic inflammatory conditions, but it can also occur with acute inflammation. Whenever you observe a severe monocytosis (> 4,000/µl), prepare a buffy coat smear to identify any particles or causative
agents that have been phagocytosed by circulating monocytes (e.g. opsonized RBCs in immune-mediated hemolytic anemia, *Ehrlichia canis* organisms, or *Histoplasma capsulatum* organisms).

4. **If inflammation is present, can it be further classified as acute, chronic, or overwhelming?** In many cases, the inflammation cannot be further classified based on the inflammatory leukogram. However, in some cases, the differential cell count is typical of acute, chronic, or overwhelming inflammation (*Table 1*).

The classic acute inflammatory leukogram in dogs and cats is characterized by neutrophilic leukocytosis with a left shift (increased numbers of immature neutrophils in circulation), which is also called a regenerative left shift. The WBC count is elevated because bone marrow production and release of granulocytes into the blood is greater than the migration of granulocytes from the peripheral blood into the tissues. A left shift is apparent because as neutrophils are being rapidly mobilized from the bone marrow, immature neutrophils (band cells) are drawn from the bone marrow maturation pool into circulation. Generally, lymphopenia is also present as a reflection of superimposed stress (glucocorticoid response). The presence of monocytosis is variable.

In chronic inflammatory conditions, the myeloid marrow has expanded enough for production to keep pace with tissue demand, and the left shift dissipates. If the inflammation is severe and localized, as in the case of a large abscess or pyometra, then the WBC count may be quite high, reaching 50,000/µl or more. In most other instances of chronic inflammation, the total WBC count is closer to normal. Animals with chronic inflammatory leukograms usually have normal lymphocyte counts. Monocyte counts are almost always elevated because of tissue necrosis and demand for phagocytosis. So a classic chronic inflammatory leukogram is characterized by a normal to slightly elevated leukocyte count (rarely dramatically elevated), a normal to slightly elevated neutrophil count, a normal or elevated lymphocyte count, and an elevated monocyte count.

Overwhelming inflammatory responses usually occur with acute conditions in which bone marrow production is unable to match tissue use. The bone marrow storage pool of neutrophils is quickly depleted and immature neutrophils are drawn into circulation, resulting in leukopenia, normal or decreased neutrophil counts, and a degenerative left shift. Monocytosis may be present because of tissue destruction. Superimposed stress lymphopenia is also common.

Recognizing and classifying inflammatory reactions is important to the interpretation of other hemogram parameters. The most common anemia in dogs and cats is the anemia of inflammatory disease. This is a mild to moderate nonregenerative anemia, resulting in a PCV as low as 30% in dogs and 25% in cats. This anemia can develop fairly rapidly (within seven to 10 days), particularly in cats in which the life span of circulating RBCs is relatively short (about 80 days). Chronic inflammatory conditions are often associated with stimulation of the immune system, hypergammaglobulinemia, and resultant elevated total protein concentrations. Whenever inflammation is severe, give special attention to platelet counts. Low platelet numbers (<100,000/µl) in conjunction with an inflammatory leukogram suggest the possibility of disseminated intravascular coagulopathy (DIC). In dogs, the presence of RBC fragments (schistocytes) in the peripheral blood can further signal DIC (*Figure 3*). Immune-mediated thrombocytopenia can cause a similar pattern but is usually associated with an even lower platelet count (<35,000/µl).

5. **Is there evidence of systemic toxemia?** Circulating toxins (i.e. systemic toxemia) can arrest the development of neutrophil precursors in the bone marrow, which can affect either cytoplasmic or nuclear development. The abnormal neutrophils produced in this way are recognized on the peripheral blood film as toxic neutrophils. Cytoplasmic features of toxemia include foamy basophilia (*Figure 4*) and the presence of small basophilic precipitates known as Döhle’s bodies.

Döhle’s bodies are a sign of mild toxemia in cats (often seen in low numbers in normal cats), but indicate serious toxemia in dogs. Nuclear changes of toxemia include bizarre nuclear shapes and cellular giantism. Systemic toxemia is usually associated with bacterial endotoxins. Infectious diseases commonly associated with severe toxemia include feline pyothorax, pyometra, and severe canine prostatitis. Toxemia can also accompany noninfectious conditions such as tissue necrosis, heavy metal toxicosis, or cytotoxic drug therapy.

**Evaluating the RBCs (erythrogram)**

RBC data include the PCV, RBC count, hemoglobin concentration, mean cell volume, and mean cell hemoglobin concentration. As stated earlier, we include total protein concentration as part of the RBC evaluation. The RBC data are used to determine whether the RBC mass is normal, reduced, or increased.

RBC mass is evaluated by assessing the PCV, hemoglobin concentration, and RBC count. For in-clipic laboratories, one reason for determining all three is to achieve some measure of internal quality control. Any deviation from the reference range should occur in all three tests to the same degree. If the results of the three tests do not correlate, consider the possibility of laboratory error.
Classifying polycythemia. If RBC mass is increased, then the animal is polycythemic. This then raises the question: Is the polycythemia relative or absolute? Relative polycythemia, the most common polycythemia recognized in veterinary medicine, is the result of hemoconcentration. Relative polycythemia is generally established based on the clinical history and signs consistent with dehydration, as well as an elevated total protein concentration. Polycythemia in the absence of these findings is absolute. Absolute polycythemia can be either primary or secondary.

Primary absolute polycythemia, also called polycythemia vera, is a myeloproliferative disease. It is a multipotential stem cell defect characterized by overproduction of all cell lines. The clinical signs—including lethargy, hyperemia, dyspnea, cardiac murmur, and splenomegaly—are attributed to hyperviscosity syndrome related primarily to increased RBC mass. A markedly increased RBC mass (e.g., PCV = 75%) in the presence of normal arterial oxygen concentrations and normal or low serum erythropoietin concentrations generally confirms the diagnosis.

Secondary absolute polycythemia is both appropriate and compensatory for hypoxemia or inappropriate and caused by increased concentrations of circulating erythropoietin. Compensatory polycythemia is present in animals recently moved to high altitudes or that suffer from pulmonary or cardiovascular disease. Inappropriate secondary polycythemia, characterized by excessive erythropoietin production, often accompanies renal carcinoma, renal cysts, hydronephrosis, and, occasionally, nonrenal tumors.

Excessive exogenous administration of erythropoietin can also cause polycythemia in dogs and cats. Furthermore, mild polycythemia can result from hyperthyroidism and hyperadrenocorticism.

Classifying anemias. If RBC mass is reduced, then the animal is anemic (Figure 5). The degree of anemia should be further considered in conjunction with plasma protein concentrations. If protein concentrations are elevated, then the animal may be dehydrated and the anemia may be more severe than the RBC mass measures indicate.

Once anemia is recognized, the next issue of concern is bone marrow responsiveness: Is the anemia regenerative or nonregenerative? If the RBC marrow responds with an increase in production of the appropriate magnitude, the anemia is regenerative (responsive). On the other hand, the anemia is nonregenerative (nonresponsive) when the increase in RBC production is not sufficient.
Evidence of RBC regeneration can be evaluated on a peripheral blood film. In dogs and cats, regeneration is indicated by the presence of polychromatophils (using Wright’s or Diff-Quik stain) or reticulocytes (using new methylene blue stain). These immature RBCs stain bluish because they contain RNA (Figure 6). Because polychromatophils and reticulocytes are larger than mature RBCs, another feature of regeneration is anisocytosis (variation in RBC size). Nucleated RBCs may also be present in small numbers, but there should always be fewer of them than polychromatophils. A large number of nucleated RBCs in the absence of polychromasia usually indicates bone marrow stromal damage; this finding is called an inappropriate nucleated RBC response (Figure 7). This process will be addressed in more detail in the discussion of lead poisoning anemia.

If the issue of regeneration is still in doubt after you evaluate stained blood films, do a reticulocyte count. As a guideline, a reticulocyte count above 60,000/µl in cats and 80,000/µl in dogs indicates a regenerative anemia. In many cases, the reticulocyte counts in dogs with regenerative anemias are much higher than 80,000/µl. Cats show a somewhat lower overall regenerative capacity than do dogs. Cats have two types of reticulocytes called aggregate and punctate. Aggregate reticulocytes indicate active RBC regeneration, while punctate reticulocytes indicate past regeneration. When performing a reticulocyte count in a cat, it is important to count only aggregate reticulocytes. In both dogs and cats, peak reticulocyte counts occur four to eight days after the onset of anemia.

Regenerative anemias can be further classified as either blood loss or hemolytic anemias. Remember that it might take one to three days for the PCV to decrease from blood loss because the severity of anemia may be masked by splenic contraction and restoration of blood volume by fluid passing from the extravascular space. A patient history of trauma or parasitic infection may suggest blood loss. Furthermore, the total protein concentration may be decreased in such cases. Another useful differentiating factor is that hemolytic anemias are generally much more regenerative than are blood loss anemias. Iron is preserved with hemolytic anemias and lost with blood loss.

Whenever hemolysis is suspected, examine RBC morphology closely. Infectious causes of hemolysis, such as *Haemobartonella canis, Haemobartonella felis, Babesia canis,* and *Babesia gibsoni,* may be visible on blood films from affected animals. In addition, certain RBC morphological abnormalities, such as spherocytes (Figure 8), schistocytes (Figure 3), and Heinz bodies (more easily recognized with new methylene blue staining) (Figure 6), can be markers for certain types of hemolysis. Spherocytosis is present with immune-mediated hemolytic anemias. Schistocytes in large numbers suggest microangiopathic hemolysis (e.g. in cases of DIC or hemangiosarcoma). In dogs, Heinz bodies in the peripheral blood confirm a diagnosis of Heinz body hemolytic anemia. In cats, large numbers of Heinz bodies are associated with such conditions as diabetes mellitus or hyperthyroidism in the absence of hemolysis (Figure 9). To confirm Heinz body hemolytic anemia in cats, Heinz bodies, anemia, and evidence of regeneration must be present.

Nonregenerative anemias lack polychromasia on the peripheral blood films. This type of anemia can be separated into two classes: nonregenerative anemias with marrow hypoplasia, and nonregenerative anemias with RBC marrow hyperplasia but ineffective erythropoiesis.

Nonregenerative anemias with RBC marrow hypoplasia are the most common anemias in dogs and cats. These are usually normocytic, normochromic anemias, based on RBC indices (mean cell volume and mean cell hemoglobin concentration) and RBC morphology. Included in this category are the anemias of inflammatory or neoplastic disease, the anemia of renal disease, the anemia of hypothyroidism, myelophthisic anemias (such as those that occur with myelofibrosis), and anemias resulting from exposure to a variety of bone marrow toxins. Pure RBC aplasia is also in this category. Cytologic evaluation of bone marrow is very useful in differentiating these various causes, but a detailed discussion of bone marrow collection and evaluation is beyond the scope of this article.

Nonregenerative anemias with ineffective erythropoiesis can result from nuclear or cytoplasmic maturation defects in RBC precursors (cytonuclear dissociation). Ineffective erythropoiesis implies that even though the RBC marrow is active, increased numbers of normal RBCs are not being released into circulation. The peripheral blood evaluation suggests the diagnosis, and the combination of peripheral blood findings and bone marrow findings confirm the diagnosis.

Nuclear maturation defect anemias result when the formation of nuclear DNA or RNA is blocked. This can occur from a deficiency of certain nutrients (e.g. vitamin B₁₂ or folic acid) or through active interference (e.g. methotrexate toxicosis). The most common nuclear maturation defect anemia in small-animal medicine is caused by feline leukemia virus (FeLV) infection. FeLV infection is thought to directly interfere with DNA synthesis. The anemia of FeLV infection can have either normocytic, normochromic RBC indices or macrocytic, normochromic indices.

In nuclear maturation defect anemias, the diagnostic finding is the presence of megaloblastic RBC precursors in peripheral blood, bone marrow, or both. Megaloblasts (Figures 10 & 11) are giant RBC precursors in which the nuclei are more immature than the cytoplasm. For example, normal metarubricytes have small pyknotic (aged, condensed) contaminants of polychromatophils (using Wright’s or Diff-Quik stain) or reticulocytes (using new methylene blue stain). These immature RBCs stain bluish because they contain RNA (Figure 6). Because polychromatophils and reticulocytes are larger than mature RBCs, another feature of regeneration is anisocytosis (variation in RBC size). Nucleated RBCs may also be present in small numbers, but there should always be fewer of them than polychromatophils. A large number of nucleated RBCs in the absence of polychromasia usually indicates bone marrow stromal damage; this finding is called an inappropriate nucleated RBC response (Figure 7). This process will be addressed in more detail in the discussion of lead poisoning anemia.

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nuclei and well-hemoglobinated cytoplasm. In contrast, megaloblastic metarubricytes have well-hemoglobinated cytoplasm, but their large nuclei are vesiculated and immature. Megaloblasts are larger than normal blood cells at the same stage of cytoplasmic development; they do not divide as often because they are unable to synthesize nucleic acids. Nucleic acid synthesis is a prerequisite of normal mitosis.

The principal cytoplasmic maturation defect anemias are the anemia of iron deficiency and the anemia of lead poisoning. In both cases, the cytoplasmic maturation defect results from inadequate hemoglobin synthesis.

Iron deficiency anemia is a consequence of chronic or severe blood loss. It is usually characterized by the presence of small RBCs with excessive areas of central pallor (microcytosis and hypochromasia) (Figure 12). Poikilocytes such as schistocytes, codocytes (target cells), and elliptocytes may also occur with iron deficiency anemia.

The anemia of lead poisoning in dogs is generally mild, with RBCs of normal size and a normal amount of hemoglobin (normocytic, normochromic). A striking finding in peripheral blood films is a marked inappropriate nucleated RBC response (Figure 7). In some cases, basophilic stippling of RBCs may be apparent. Other causes of inappropriate nucleated RBC responses include hyperadrenocorticism, endotoxemia, splenic disorders, fractures, and extramedullary hematopoiesis. All of these are associated with mild responses (five to 10 nucleated RBCs/100 WBCs). Suspect lead poisoning whenever more than 10 nucleated RBCs/100 WBCs and minimal polychromasia are seen in dogs. In cats, inappropriate nucleated RBC responses are most commonly associated with FeLV infections (Figure 13).
Evaluating the platelets

An assessment of platelet numbers is an important part of every CBC. As with RBCs, the principal issue is whether platelet numbers are normal, increased (thrombocytosis), or reduced (thrombocytopenia).

Thrombocytosis is rare. When the number of platelets in dogs or cats approaches 1 million/μl, consider platelet leukemia (primary thrombocytHEMA), megakaryocytic myelosis). More commonly, thrombocytosis is less marked, and reactive responses are probably more likely. For example, stimulation of RBC production in any regenerative anemia also stimulates platelet production.

Thrombocytopenia is more common than thrombocytosis and can be of great clinical significance. Platelet counts below 50,000/μl can lead to overt bleeding. Platelet clumping can give a falsely low platelet count, particularly in cats. Platelet clumping frequently interferes with results from impedance counters because aggregated platelets may be included in the RBC count. If you obtain a low platelet count in a cat by using impedance counter technology, use another method, such as blood film examination or laser flow cytometry, to avoid an unnecessary workup.

Thrombocytopenia can result from:
- decreased platelet production (e.g., with estrogen toxicity or infection with FeLV or feline immunodeficiency virus)
- increased peripheral use of platelets (e.g., in DIC, acute ehrlichiosis, or Rocky Mountain spotted fever)
- peripheral destruction of platelets (e.g., in immune-mediated thrombocytopenia)
- sequestration of platelets in the spleen (e.g., in hypersplenism). Hypersplenism is rare, poorly documented in animals, and generally can be ruled out in the absence of splenomegaly.

The next step in classifying the causes of thrombocytopenia is bone marrow evaluation. Hypoproliferative thrombocytopenia is characterized by a decreased number of megakaryocytes in the bone marrow. Some hypoproliferative thrombocytopenias may be immune-mediated and steroid- or immunosuppressive-responsive. Both utilization thrombocytopenia (DIC) and destruction thrombocytopenia (immune-mediated disease) are characterized by a normal to increased number of bone marrow megakaryocytes. In dogs with an inflammatory leukogram or schistocytes on the blood film, DIC is a strong possibility, so perform a coagulation profile. After ruling out other causes of peripheral platelet use (e.g., ehrlichiosis, Rocky Mountain spotted fever), you can attempt antiplatelet antibody tests. Kansas State University currently offers platelet-bound antibody testing. Based on the diagnostic findings, you can then institute appropriate therapy.

Conclusion

Laboratory medicine continues to evolve as research and technology create new tests and improve current diagnostics. We hope this review of current concepts in hematology will assist veterinarians and veterinary technicians in their constant efforts to improve patient care through laboratory diagnostics.

REFERENCE


SUGGESTED READINGS