Hematology 101

Blanche P. Alter, MD, MPH, FAAP
Clinical Genetics Branch
Division of Cancer Epidemiology and Genetics
Bethesda, MD

Hematocrits

- Plasma
- White cells
- Red cells

Normal, Hemorrhage, IDA, Leukemia, Hemolysis, B12, P Vera

Normal Peripheral Blood

- Red blood cells
- Platelets
- White blood cells

Aplastic Anemia Peripheral Blood

Red Cells

- Contain a red pigment, hemoglobin
- Carry oxygen from the lung to other tissues that need it
  - Muscles, liver, kidney, heart, brain
- Normally live 4 months

Reticulocytes

Red cells newly released from bone marrow
Fetal Hemoglobin
Kleihauer-Betke stain

Platelets
- Help blood clot
- Live 7-10 days
- Low numbers can lead to:
  - Bruising
  - Petechiae (tiny red dots)
  - Nosebleeds
  - Internal bleeding

Types of White Cells (Leukocytes)

<table>
<thead>
<tr>
<th>Type</th>
<th>Life Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phagocytes (eaters):</td>
<td></td>
</tr>
<tr>
<td>Neutrophil</td>
<td>hours</td>
</tr>
<tr>
<td>Monocyte</td>
<td>days</td>
</tr>
<tr>
<td>Eosinophil</td>
<td>hours</td>
</tr>
<tr>
<td>Basophil</td>
<td>hours</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>months-years</td>
</tr>
</tbody>
</table>

White Blood Cell Functions
- Neutrophils - eat bacteria and fungus
- Lymphocytes - direct the other cells and make antibodies
- Monocytes - eat particles coated with antibody
- Eosinophils - allergies and fight parasites
- Basophils - allergies

Neutrophils (Phagocytes)
- Polymorphonuclear (PMN), segmented, granulocytes
- Bands, juveniles = early forms
- First line of defense against bacterial infection is intact skin and lining of the mouth, throat and intestines
- Second line of defense is neutrophils, which eat bacteria and kill them
- Low neutrophil number increases susceptibility to bacterial and fungal infections

Lymphocytes
- Regulate other white cells
- Make antibodies
  - Proteins that act as flags to stick to bacteria and viruses
- Tell other cells to eat things
Monocytes

- Phagocytes
- Become tissue macrophages
  - Cells in the tissues that eat particles tagged with antibodies

CBC Machine

- Draw blood from the tube into an electronic counter
- Result is called the complete blood count (CBC)

Blood Counts

<table>
<thead>
<tr>
<th>CBC Machine</th>
<th>CBC Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw blood from the</td>
<td>CBC Machine</td>
</tr>
<tr>
<td>tube into an electronic counter</td>
<td>Result is called the complete blood count (CBC)</td>
</tr>
</tbody>
</table>

Red Cells

- Hemoglobin (Hb, Hgb)
  - 12-15 grams/100 ml (g/dl) [lower for children]
- Hematocrit (Hct)
  - 35 to 45%

Anemia = Low Hb/Hct (H/H)

Blood Counts

<table>
<thead>
<tr>
<th>WBC</th>
<th>RBC</th>
<th>Hb</th>
<th>Hct</th>
<th>MCV</th>
<th>MCH</th>
<th>MCHC</th>
<th>RDW</th>
<th>Plat</th>
<th>MPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>4.48</td>
<td>13.6</td>
<td>38.7</td>
<td>80.4</td>
<td>32.7</td>
<td>33.3</td>
<td>3.36</td>
<td>8.4</td>
<td></td>
</tr>
</tbody>
</table>

Platelets

- Platelet count (Plt)
  - 150,000 to 400,000/μl

Thrombocytopenia = low platelets

White Blood Cells (Leukocytes)

- WBC = white blood cell count
  - 5000–10,000/μl, 5 – 10 thousand/μl
- WBC differential
  - % Neutrophils, bands, lymphocytes, monocytes, eosinophils, basophils

Leukopenia = low WBC

Bacterium tagged by an antibody
**Absolute Neutrophil Count (ANC)**

- ANC = WBC x % Neutrophils
  - e.g. WBC = 5000/μl, 30% neutrophils
  - ANC = 5000 x 0.30 = 1500/μl
- Normal: above 1500/μl
- OK: above 500
- Low: 200-500
- Very low: below 200

*Neutropenia* = low neutrophils

---

**CBC Summary**

- Quick and easy assessment of numbers of blood cells
- Relatively inexpensive
- No single test tells us more about a blood disorder
- Measures all three cell types (RBC, WBC, platelets)
- Provides other valuable details

---

**Causes of Anemia**

- Decreased production
  - Decreased reticulocytes
- Increased destruction
  - Increased reticulocytes
- Blood loss
  - Increased reticulocytes

---

**Definitions**

- Aplastic Anemia (AA):
  - Pancytopenia due to decreased production
  - Hypocellular bone marrow
- Leukemia:
  - Malignant proliferation of immature cells
- Myelodysplastic syndrome (MDS):
  - Cytopenia with hypercellular bone marrow

---

**Bone Marrow Equipment**

- Aspirate
- Biopsy

---

**Bone Marrow Biopsy**

- Normal
- Aplastic
Normal Bone Marrow Aspirate

Erythroid (red cells)  Myeloid (white cells)

Aplastic Anemia Bone Marrow Aspirate

Bone Marrow Iron

Leukemia Bone Marrow

Hematopoiesis

- Formation and development of blood cells
- Takes place in the bone marrow
- Involves "stem cells"
BM Cultures
- CFU-E: colony-forming unit, erythroid
- BFU-E: burst-forming unit, erythroid
- CFU-C: colony-forming unit in culture
- CFU-GM: colony-forming unit, granulocyte-macrophage

CFU-E and BFU-E
- Erythroid: megaloblastic, multinucleation, nuclear fragments, increased immature forms, ring sideroblasts
- Myeloid: increased immature forms, hypo/hyper-granulation
- Megakaryocytes: hypo-/hyper-lobulated, small forms, increased nuclear-cytoplasmic ratio

Bone Marrow in MDS - Erythroid

Bone Marrow in MDS - myeloid and megakaryocytic
FAB CLASSIFICATION
- No MDS
- RA = refractory anemia
- RARS = ring sideroblasts
- RAEB = RA with excess blasts (5-20%)
- CMML = chronic myelomonocytic leukemia, PB monocytes >1000/μL
- RAEBT = RA in transformation

WHO Classification
- RCUD: refractory cytopenia with unilineage dysplasia (≥10% cells in one lineage)
  - RA, RN, RT: anemia, neutropenia, thrombocytopenia
- RARS: ring sideroblasts
- RCMD: multilineage dysplasia (≥2 lineages)
- RAEB-1: 5-9% blasts
- RAEB-2: 10-19% blasts
- MDS-U: unclassified: dysplasia <10% cells, + clone
- MDS del(5q): anemia with isolated del(5q)

Hematopoiesis

Blood and Marrow MDS Study
- Aspirate: Morphology
- Biopsy: Cellularity
- Cytochemistry: PAS, MPO, dual esterase, iron
- Flow cytometry: Lymphocytes, granulocytes
- Oncogenes: p53, p21
- Cytogenetics:
  - Classical G banding,
  - FISH (fluorescence in situ hybridization),
  - CGH (comparative genomic hybridization)

Prepared by
- Blanche P Alter, MD, MPH
  National Cancer Institute
- Greg Kato, MD
  National Heart, Lung, and Blood Institute
- M Tarek Elghetany, MD
  University of Texas Medical Branch

www.marrowfailure.cancer.gov

The End