Chapter 3 Disorder of Local Blood Circulation
Disorder of vascular flow may be divided into general and local categories.

The local disorders contain:

① **Derangement of local blood volume**: hyperemia and ischemia;

② **Derangement of blood properties and content**: thrombosis, embolism and infarction;

③ **Derangements of vascular permeability and anatomic integrity**: edema, hemorrhage.
hyperemia and ischemia
Section 1 Hyperemia

Local increased volume of blood caused by dilatation of the small vessels.

1. Arterial hyperemia (active hyperemia)
   - It results from an augmented arterial inflow.
   - Examples: the muscles during exercise, at sites of inflammation, and in the pleasing neurovascular dilatation termed blushing.

   • Active hyperemia causes increased metabolism and function of the organ. It is beneficial to the organism. Active hyperemia of body surface shows red in color and increase in local temperature.
2. Venous Hyperemia (passive hyperemia, congestion)

- It results from diminished venous drainage such as follows cardiac failure or obstructive venous disease. Also called venous hyperemia. When body surface is involved, the skin show red-blue color owing to deoxgenation of impounded red cells—cyanosis.

**Etiology**

1. Compression on vein
2. Intravenous obstruction
3. Cardiac failure

**Morphology**

- Congested organ increases in size and weight, and shows dark-red color.
The consequences of congestion:

1. Congestive edema and hemorrhage.
   Congestion of capillary beds is closely related to the development of edema. If the edematous fluids contain lots of red blood cells, it is referred to congestive hemorrhage.

2. Congestive sclerosis.
   Chronic passive congestion may lead to hypoxic atrophy or degeneration or death of parenchymal cells, followed by proliferation of fibrous tissue.

3. Atrophy of parenchymal cells.

4. Formation collateral blood circulation.
   Examples: collateral circulation formed in cirrhosis.
Pulmonary edema

edematous fluid
Congestive sclerosis of the liver
(1) Pulmonary Congestion

Chronic lungs congestion: congestion and edema seen mainly in left ventricular failure.

Normal  Congestion  Fibrosis of alveolar septa
Acute Pulmonary Congestion and edema
Chronic pulmonary congestion

G:
The lung is harder in consistency, dark brown in gross view, which is referred to “brown induration of the lung”.

H:
The alveolar septa have become thickened and fibrotic, and the alveolar spaces contain hemosiderin or heart failure cell (hemosiderin-laden macrophage).

Hemosiderin-laden macrophage appear in alveolar space in chronic (left) heart failure, is called heart failure cell.
Chronic pulmonary congestion

G: brown induration of the lung”.  
M: the septa have become thickened and fibrotic, and the alveolar spaces contain hemosiderin, **heart failure cells** can be seen.
Chronic pulmonary congestion
(2) **Chronic congestion of liver**

It is caused by chronic right heart failure. The central hepatocytes degenerated; the periportal hepatocytes, better oxygenated because of their proximity to hepatic arterioles, experience less severe hypoxia and may only develop fatty change.

**G:** yellow stripes alternated with red stripes on the section surface of the liver (*nutmeg liver*).

**H:** red blood cell filled in dilated hepatic sinusoid and central vein, some hepatocytes were atrophied and fatty changed.
G: yellow stripes alternated with red stripes on the section surface of the liver (nutmeg liver).

H: red blood cell filled in dilated hepatic sinusoid and central vein, some hepatocytes were atrophied and fatty changed.

Chronic congestion of liver
Congestion of liver
Sinusoid dilated and filled red blood cells
Section 2 Hemorrhage

- Extravasation of blood caused by rupture of blood vessel.

- **Hematoma**: Accumulation of large amount of blood within the tissue of the body.

- **Hemothorax, hemopericardium, hemoperitoneum, hemarthrosis**: Blood accumulation in body cavities as thoracic cavity, pericardial cavity, peritoneal cavity and arthritic cavity respectively.

- **Petechiae**: Minute hemorrhage into skin, mucous membrane or serosal surface.

- **Purpura**: Slight larger hemorrhage.

- **Ecchymosis**: A large subcutaneous hematoma.
Cerebral Hemorrhage
It is a common complication of hypertension

Petechia & Ecchymosis
Section 3 Thrombosis

- Thrombosis refers to the process of formation of an adherent clotted mass of blood within the cardiovascular system in a living body.
- The clotted mass is thrombus.

*Three required factors for thrombosis:*
1. endothelial injury;
2. alterations in normal blood flow;
3. blood hypercoagulability
Normal hemostasis depends on balance between coagulative and procoagulant system or activation and inactivation of clotting factors.

Three key contributors to hemostasis:
1. The vascular wall, particularly endothelium and underlying collagen.
2. Platelets.
3. Clotting factors.
Factors for thrombosis

1. Endothelial injury
   - On the one hand, endothelial cells possess antiplatelet, anticoagulant, and fibrinolytic properties; On the other hand, they exert procogulant functions.
   - Intact endothelium insulates the blood platelets and coagulation proteins from the highly thrombogenic subendothelial components, principally collagen.
   - Damaged endothelium has a dominant influence to thrombogenesis, and the only one factor may lead to thrombosis.
   - Examples: ulcerated atherosclerotic plaques; vascular traumatic or inflammatory injury; endocardium in the site of myocardial infarction or myocarditis.
Favor & inhibit thrombosis
Coagulation cascade
(HMWK: high molecular-weight kininogin)
(2) Alteration of blood flow (stasis and turbulence)

- In normal laminar blood flow, the formed elements are separated from the endothelial surface by plasmatic zone.
- Normal laminar blood flow disrupt laminar flow in stasis and turbulence conditions.
  ① disrupt laminar flow permit platelets to contact with the endothelium;
  ② prevent dilution of activated clotting factors;
  ③ the turbulence is a injury factors for endothelium;
  ④ promote endothelial cell hypoxia and injury, predisposing to platelet and fibrin deposition as well as reducing release of t-PA;
- Examples: thrombus are likely formed in vein than in artery.
(3) **Hypercoagulability**

- An alteration of the blood or, specifically, the clotting mechanism that in some way predisposes to thrombosis.

- Hypercoagulability can be seen in many clinical settings such as severe trauma, burns, disseminated cancer, long term use of oral contraceptives.
Morphogenesis of thrombi

① Endothelial injury → platelets adhesion, release reaction and aggregation.

Platelets activation → release reaction (ADP, TxA2, Ca++) → platelet aggregation.

② Intrinsic and extrinsic coagulation sequence:

prothrombin → thrombin

fibrinogen → fibrin
C14 延续性血栓形成过程

C13 正常血小板(上)、肾小球
毛细血管内血小板栓(脱落粒)(下)
Types of thrombi

1. **pale thrombus**: dry, friable gray mass
   transection: darker gray lines of platelets (Zahn’s line)
   H. Platelet trabeculae formation (head).
   - vegetation, arterial thrombus, mural thrombi

2. **mixed thrombus**: white thrombus intermingled with red thrombus (body).
   - Venous thrombus, globular thrombus in aneurysms

3. **red thrombus**: dark red in color, laminations are not well developed and composed of rbc and fibrin (tail).
   - Venous thrombus

4. **Hyaline thrombus**: DIC(microthrombus)
Components of thrombi:

Pale thrombus: plt
Mixed thrombus: plt.+RBC.+WBC.+ fibrin
Red thrombus: Rbc+fibrin
Hyaline thrombus: fibrin
Mixed thrombus: plt.+RBC.+WBC+ fibrin
Types of thrombi

Classification according morphology or relationship to walls of vessel or heart:

① **Mural thrombi:** arterial thrombi arise in heart chambers or in the aortic lumen, they are usually adhere to the wall.

② **Ball thrombi:** thrombus at atrium or ball-shaped.

③ **Occlusive thrombus:** Thrombus block the vesicular lumen.

④ **Vegetations:** Thrombus at cardiac valve.
Mural & Occlusive thrombus

Figure 3.20. Top, Laminated mural thrombus in the jugular vein. Bottom, Sand bank in the Canary Islands.

Figure 3.22. Occlusive (coagulation) thrombus in a femoral vein.
Figure 2.49. Verrucous endocarditis of the aortic valve.
Coronary artery thrombi forming with hemorrhage
Hyaline thrombus
4. The outcome of thrombus

(1) **Softening, resolution and absorption**: due to the fibrinolysis, small thrombi may be completely absorbed; large thrombi may be sources of emboli.

(2) **Organization and recanalization**. Thrombi replaced by granulation tissue; The blocked vessel lumen be re-connected.

(3) **Calcification**: leading formation of phlebolith, arteriolith.
Organization & Recanalization

Figure 2.21 Organizing thrombus; HE stain.

Figure 2.22 Recanalized arterial thrombus; elastica-van Gieson's stain.
Microcirculatory Thrombosis

Disseminated intravascular coagulation (DIC)

- DIC is the sudden or insidious onset of widespread fibrin thrombi in the microcirculation, and subsequent hemorrhage due to depletion of coagulatic factors.
- Etiology and mechanism: it is a complication of some diseases (trauma, severe infection, shock, carcinoma etc.) which activate the blood clotting processes.
- The simplest mechanism involves the release of tissue factor into the circulation (obstetric complication, carcinomas).
- Morphology: The microthrombi are composed of fibrin, and found in the arterioles and capillaries of the kidney, adrenals, brain and heart.
Microcirculatory Thrombosis
The influence of thrombus

Advantages: hemostasis in injurious vessel.

Disadvantages:

(1) obstruction of arteries and veins.
(2) sources of emboli.
(3) heart valves malformation.
(4) hemorrhage: DIC also called as “consumption coagulopathy”.
Section 4 Embolism

• Embolism refers to occlusion of some part of the cardiovascular system by any abnormal mass carried there in the blood stream.

• The transported mass is embolus. It is a detached intravascular solid, liquid, or gaseous mass.
1. Routes of embolus transportation

(1) Venous embolus --- pulmonary embolization and infarction
(2) Arteria embolus --- the important organs of body, such as coronary, cerebral, liver and kidney artery.
(3) Digestive system embolus--- intrahepatic portal vein embolus embolism.
(4) Venous embolus from right heart to left heart cause arteria system embolism, known as crossed embolism.
(5) Large venous embolism may travel against the direction of blood flow to obstruct small vein known as retrograde embolism.

The pathways of embolism
2. Types of embolism

(1) Thromboembolism

- Pulmonary embolism most commonly originates from thrombus of lower limb. The prognosis depends on the size of the occluded vessel and the status of the patient’s cardiovascular system.
  
  * Large embolus: fatal. (sudden death)

  Mechanical obstruction + severe resistant pressure on the right heart (acute cor pulmonale) + reflexive vascular and bronchial spasm.

  Small emboli obstruct small branches of pulmonary artery: The thrombi can be resolved and so of little significance.

- If bronchial circulation is insufficiency (chronic passive congestion of lung), small emboli may produce either pulmonary hemorrhagic infarction.
pulmonary embolization
② Systemic Embolism

- Emboli traveling within the arterial circulation.
- Emboli usually arise from **mural thrombi** in the left ventricle or atrium, from **vegetations** on the left side valves, and occasionally from thrombi on the aorta (atherosclerotic plaque).

- They produce occlusion of blood stream most frequently in the **lower extremities, brain, intestine, spleen, and the kidneys**, often result to **infarcts or gangrene**.

- The consequences of systemic emboli depend on the extent of collateral vascular supply in the affected tissue, the tissue’s vulnerability to ischemia, and the caliber of the vessel occluded.
(2) Fat embolism

- Fat droplets appear in the circulation and obstruct small vessel. The causes include: fracture of long bone, severe soft tissue trauma and burns.

- Although traumatic fat embolism can be demonstrated anatomically in some 90% of individuals with severe bone injury, only 1% of such patients show clinical findings.

- Fat embolism syndrome is characterized by pulmonary insufficiency, and is fatal in about 10% of cases. Typically, the symptoms appear 1 to 3 days after injury, with sudden onset of tachypnea, dyspnea, and tachycardia.

- Sequences: The prognosis of fat embolism depends on the quantity and site of embolism.
Fat embolism in lung

Alveolar septal capillaries and small arteries are full of dark red stained fat microglobule (Sudan stain)
Fat embolism

① Pulmonary fat embolism

9~20g fat → 75% pulmonary arteries are occluded → pulmonary edema, hemorrhage, atelectasis → asphyxiation, right sided heart failure.

② Lung-brain-kidney-skin embolism syndrome

<20μm fat droplets may enter systemic circulation and result in embolism. Neurologic symptoms, skin ecchymosis may appear.
(3) Gas embolism
Gas bubbles within the circulation obstruct blood flow.

① Air embolism
• As a complication of trauma (chest), cardio-thoracic surgery, various diagnostic or therapeutic procedures, or rupture of veins during delivery.

Sequences:
- Small volume: absorbed
- >100ml: acute distress.
- >300ml: fatal due to pulmonary embolism.
Decompression sickness (cassion disease)

- Decompression sickness occurs when individuals encounter sudden changes in atmospheric pressure.

- When decompressed rapidly from higher atmospheric pressure to a lower one, dissolved gas may dissociate and bubble out of the blood, tissue fluid, and fat. The nitrogen is of low solubility and persists as minute bubbles to obstruct the blood vessel.

- **Examples:** in deep sea divers, in underwater construction workers, in aviators

- Cassion disease may cause ache of muscle, articulation or infarction.
(4) Amniotic fluid embolism

• A grave but fortunately uncommon complication of labor and the immediate postpartum period (1 per 50,000 deliveries).
• Etiology and mechanism: After rupture of membranes, some of the amniotic fluid may be forced to maternal circulation by vigorous uterine contractions via teared uterine sinusoids.

• It is now suspected that vasoactive substances within the amniotic fluid such as prostaglandins may be the cause of pulmonary vasoconstriction.

• Morphology: The classic findings in the pulmonary arteries and capillaries at autopsy are epithelial squames from fetal skin, lanugo hairs, fat from vernix caseosa, and mucin, presumed to be from the fetal GIT.
Amniotic fluid embolism
Epithelial squames in myocardial vessels
(5) Other types of embolism

Tumor cells, parasites and cholesterol crystal may cause embolism
Section 5 Infarction

• Ischemic necrosis caused by occlusion of either its arterial supply or its venous drainage. The process of infarct formation is called as infarction.

• 1. Causes and factors that determine the development of infarct

• (1) Nature of vascular supply.
  ① Effective anastomosis
  ② Double blood supply (liver, lung etc)

• (2) Rate of development of occlusion

• (3) Vulnerability of the organ or tissue to hypoxia (nerve cells, myocardial muscle > fibroblasts)

• (4) Oxygen carrying capacity of blood: The anemic or cyanotic patient tolerates arterial insufficiency less well than normal person.
2. Types of infarct

(1) **White infarct (anemic infarct):** It results from arterial occlusion, commonly seen in compact, solid organs with less collateral circulation (kidneys, spleen, and heart). The solidity of the tissue limits the amount of hemorrhage that can seep into the area of ischemic necrosis from adjoining capillary beds.

(2) **Red infarct (hemorrhagic infarct):**

- Red infarct of intestine: Limited venous outflow due to vascular obstruction + by pass channels cannot develop.
- It occurs in: 1) loose tissues (lung) that allow blood to accumulate in the infarcted zone; 2) tissues with dual circulations (lung and small intestine), permitting flow of blood from the unobstructed vascular channel into the necrotic area;

(3) **Septic infarct:** infarct caused by septic emboli.
Anemic infarct
Myocardial infarct
Anemic infarct of kidney
Hyperemic and hemorrhagic zone on the border (↑)
Anemic infarct of spleen
3. Morphology of infarct

G: All infarcts (red and white), tend to be wedge-shaped, the occluded vessel at the apex and the periphery of the organ forming the base.

H. Necrotic tissue surrounding with hyperemic and hemorrhagic zone.

- Compact organs have relative little hemorrhage, the necrotic area is gradually decolorized (rbc are lysed and removed from the area), and appears pale or yellow-white (white infarct).

- Organs of soft, loose tissue with double supply, infarcts tend to remain hemorrhagic (Red infarct) and show dark red colour.
Hemorrhagic (Red) infarct) of intestine
Pulmonary hemorrhagic infarct

Hemorrhagic infarct of the intestine
4. Fate of infarct

(1) Small infarct: softened, absorbed
(2) Large infarct: organization and scar formation
(3) Septic infarct: abscess formation
(4) Infarction of brain, myocardium or lung: sometimes may cause sudden death.
Edema

• Pitting edema

• Pulmonary edema: Occur in left heart failure, ARDS, allergy, etc.

• Cerebral edema: may cause hernia cerebri.